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FLOOD PREPAREDNESS PLANNING: METROPOLITAN PHOENIX AREA.(U)
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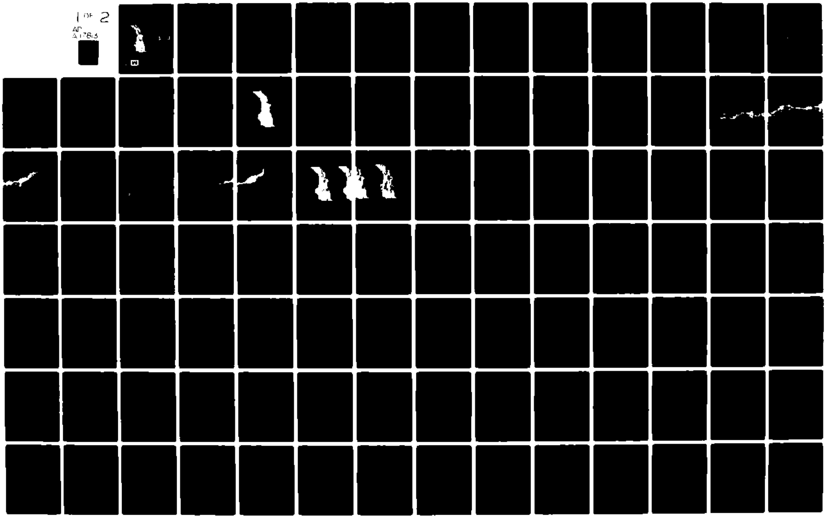

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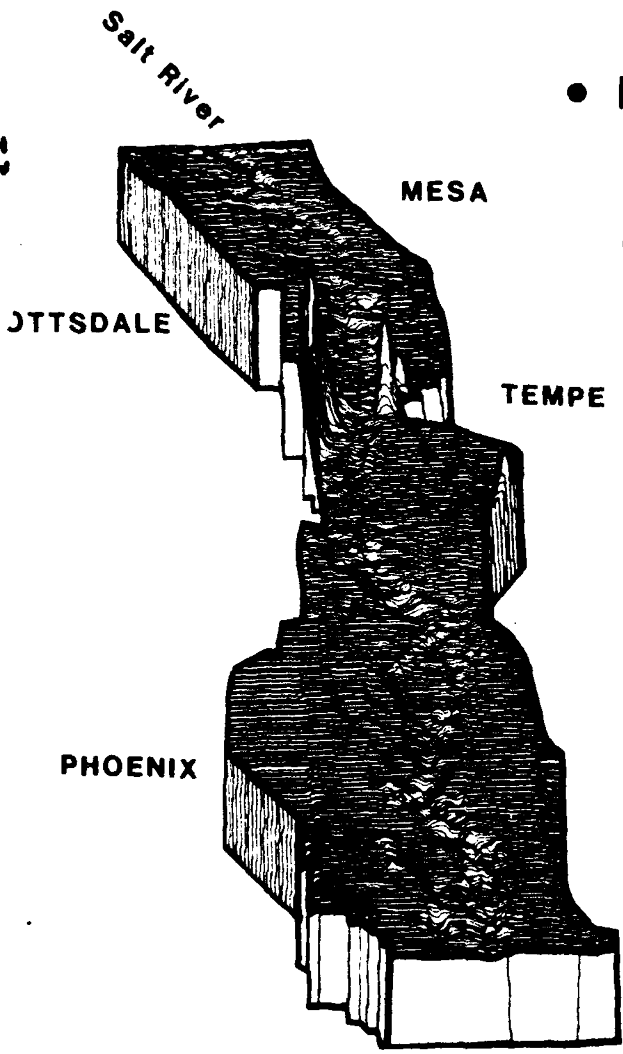

- Flood Threat Recognition
- Warning
- Emergency Actions
- Recovery
- Continuous Management

JANUARY 1982

The Hydrologic Engineering Center
Water Resources Support Center
US Army Corps of Engineers
Davis, California 95616

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The report, Flood Preparedness Planning, Metropolitan Phoenix Area, was prepared by the Hydrologic Engineering Center (HEC) for the Los Angeles District, Corps of Engineers. The Stage II level planning study investigated enhancement potentials for existing flood emergency preparedness plans. The study used an existing grid cell data bank and the DAMCAL and EAD computer programs to determine existing and modified expected annual damage values. Feasibility assessments included use of interviews, flood scenarios as well as the analytical techniques. Report findings are presented.

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LOS ANGELES DISTRICT
PHOENIX AREA OFFICE

FLOOD PREPAREDNESS PLANNING
METROPOLITAN PHOENIX AREA

January 1982

Prepared by
The Hydrologic Engineering Center
609 2nd Street
Davis, California 95616

FORWARD

This report, Flood Preparedness Planning, Metropolitan Phoenix Area, was prepared by the Hydrologic Engineering Center (HEC) for the Los Angeles District, Corps of Engineers. The report is an enhancement of a Stage II planning working document developed for the District in 1980. The continued growing interest in flood preparedness planning and geographic information systems (grid cell data bases) by other Districts has resulted in numerous requests for the original working document. Subsequently, the HEC has decided to upgrade the original working document. The primary objective is to enable others performing similar preparedness investigations to become familiar with the adopted terminology, general concepts, and evaluation procedures presented herein. Another objective is to demonstrate the analytical capability of the Spatial Analysis Methods (HEC-SAM) of using spatial gridded data in evaluating the feasibility of implementing flood preparedness plans. It is hoped that the report provides readers with insights into the applicability and evaluation techniques of similar planning or technical services studies involving flood preparedness plans.

PREFACE

Preparedness planning procedures are rapidly gaining acceptance by governmental agencies and the general public as a legitimate means to reduce the impacts of natural and man-related disasters. Although, elements of preparedness plans (warnings, evacuation, temporary protection measures, disaster relief programs, etc.) have been implemented throughout history, only recently has comprehensive and coordinated predisaster planning been attempted. This is due, in part, to social scientists who have advocated the need for preparedness plans for nearly two decades, using scenario settings to describe potential disaster consequences in the literature. Although these actions provided awareness of a problem, it wasn't until acceptance by the planning disciplines that emergency disaster planning procedures received credence as a viable means of reducing disaster related losses. Reasons for emerging acceptance can be summarized as institutional and social recognition that planned emergency actions can significantly lessen threat to life and reduce social and economic disruption resulting from disasters.

Alternative means to mitigate natural and man-related disasters have been categorized as: (a) measures designed to modify the event, or (b) measures developed to modify loss susceptibility from a disaster occurrence. Emphasis has been placed on means of modifying loss susceptibility for most types of disasters, e.g., droughts, hurricanes, tornadoes, and earthquakes. A noticable exception to this was flood-event modification measures (reservoirs, channels, and diversions) implemented during the first two-thirds of this century. The late 1960's and 1970's brought about major philosophical changes and a public awareness of the need to plan and formulate flood loss reduction measures that provided choices for a broad range of considerations. These "nonstructural measures," presented less environmentally disruptive opportunities for mitigation of flood losses by emphasizing modifications to loss susceptibility instead of event control alternatives. Nonstructural measures have been categorized (James 1974; Davis 1976) as measures which provide: (a) modifications to existing structures (permanent evacuation and floodproofing, etc.); (b) management of future development (regulatory policies, etc.) and flood preparedness plans (recognition, warnings, emergency action, etc.). This is the framework from which flood preparedness has emerged.

ACKNOWLEDGEMENTS

Numerous people deserve recognition for their participation in the preparation of this report. The study was conducted by Michael W. Burnham under the supervision of Darryl W. Davis, Chief, Planning Analysis Branch (PAB), The Hydrologic Engineering Center (HEC), Corps of Engineers, Davis, California. Brian W. Smith and Rochelle Barkin, PAB, HEC, performed many evaluations and developed the graphic displays. Bill S. Eichert was director of the Hydrologic Engineering Center during the conduct of the study.

Special acknowledgement and thanks is made to H. James Owen, private consultant, whose nationally recognized expertise in the subject field was called upon numerous times during the study. Mr. Owen was the general advisor throughout the investigation; he researched and drafted selected segments of the report and conducted many of the personal interviews.

Several people in the Corps of Engineers, Los Angeles District, provided valuable guidance and assistance. They include: Will Worthington, Chief, Urban Studies Section; Joe Dixon and Alan Chin who coordinated the investigation; and Stephanie Ostrom who was the princpal contact in Phoenix. Frank McDonald and Joe Mantey provided much of the background flood damage data. Glenn Masburn and Nick Aldermyer provided the basic hydraulic and hydrologic data used in the investigation.

Many Federal, State and local government personnel, private consultants, and business people of the Phoenix metropolitan area who were interviewed regarding the study deserve special recognition for their friendliness, understanding and assistance throughout the investigation. It was through their cooperation and information that the fundamental assumptions and enhancement opportunities were formulated.

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CHAPTER I

INTRODUCTION AND OVERVIEW

Scope and Purpose

The purpose of this investigation was to formulate and assess the value of enhancements to existing flood preparedness planning arrangements. Flood preparedness plans are defined as predetermined procedures and actions implemented during a crisis to mitigate flood losses. Preparedness plans consist of components that provide for: flood threat recognition, warning dissemination, emergency response actions, post flood recovery and reoccupation, and continuous plan management. Principal consi[illegible]ation was given to: (a) the reduction of the risk to life, (b) reduction of direct pu[illegible] and private property damage, and (c) minimization of social disruption. Preparedne[illegible]lan enhancements that result from the study are intended to provide a means of l[illegible]g the impact of flood disasters until other feasible measures are implemented, [illegible] to augment the effectiveness of such measures as might be implemented. Other objectives were to illustrate preparedness planning concepts for non-flash flood metropolitan areas and to advance the state-of-the-art in the analysis procedures for flood preparedness planning investigations.

The investigation is part of the comprehensive Central Arizona Water Control Study (CAWCS) being conducted jointly by the Bureau of Reclamation and the Corps of Engineers. This study represents one of the nonstructural alternatives being investigated by the Corps.

The study area includes a major portion of the Salt River Valley of Central Arizona, which lies almost entirely within Maricopa County. The investigation is limited to direct flooding and associated impacts from the Salt, Gila, and Agua Fria Rivers in the metropolitan area. Smaller rivers and washes, in particular those of a flash flood nature, are not addressed herein. Specifically, the study is bounded by: the Salt River from Granite Reef Dam to the confluence with the Gila River, the Gila River from its confluence with the Salt River west of Phoenix to Gillespie Dam; and the Agua Fria River from Waddell Dam to its confluence with the Gila River. Since reservoir operation practices on the three major upstream watersheds have a direct bearing on the study area, these conditions are also described as necessary. Figure I-1 shows the study

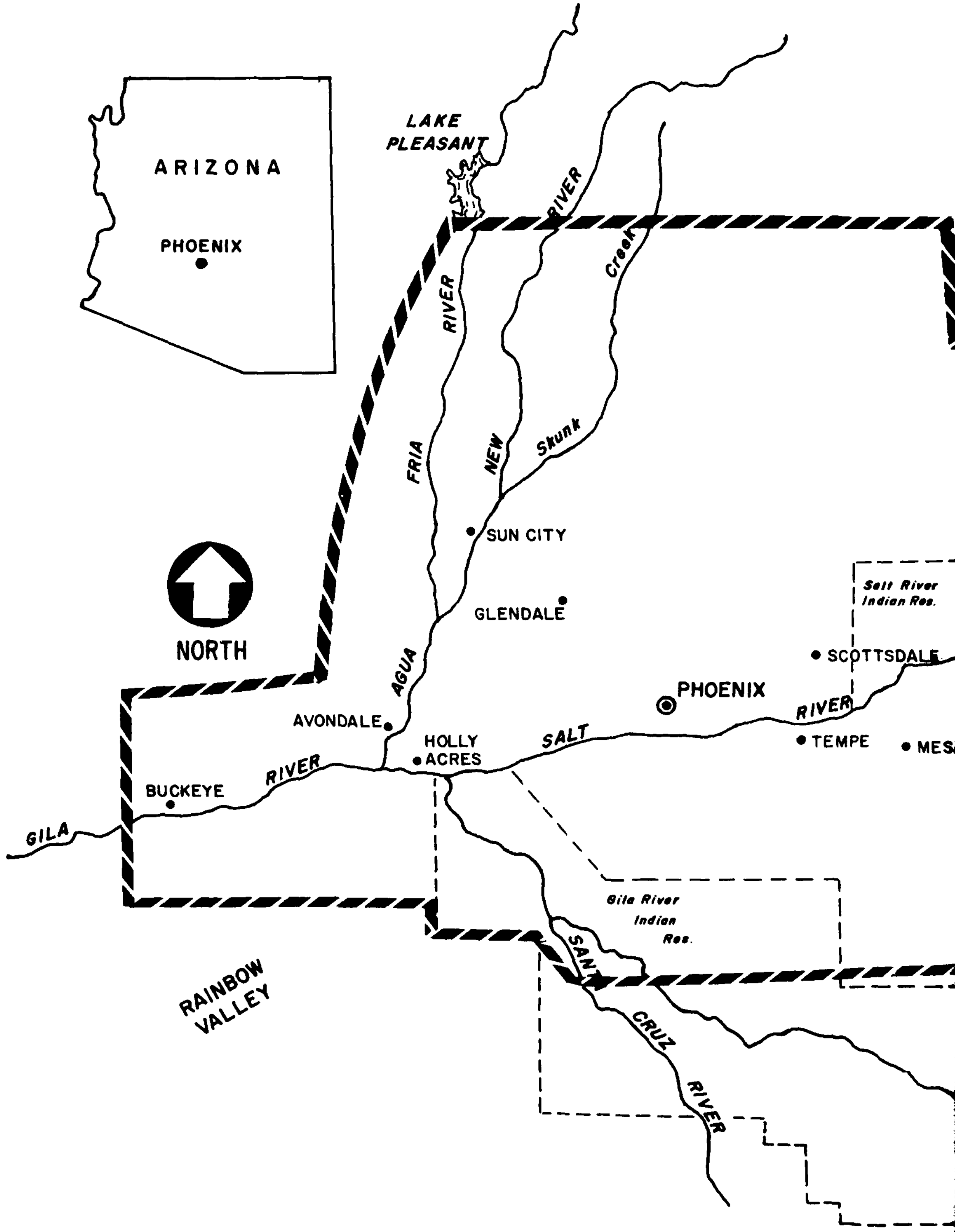
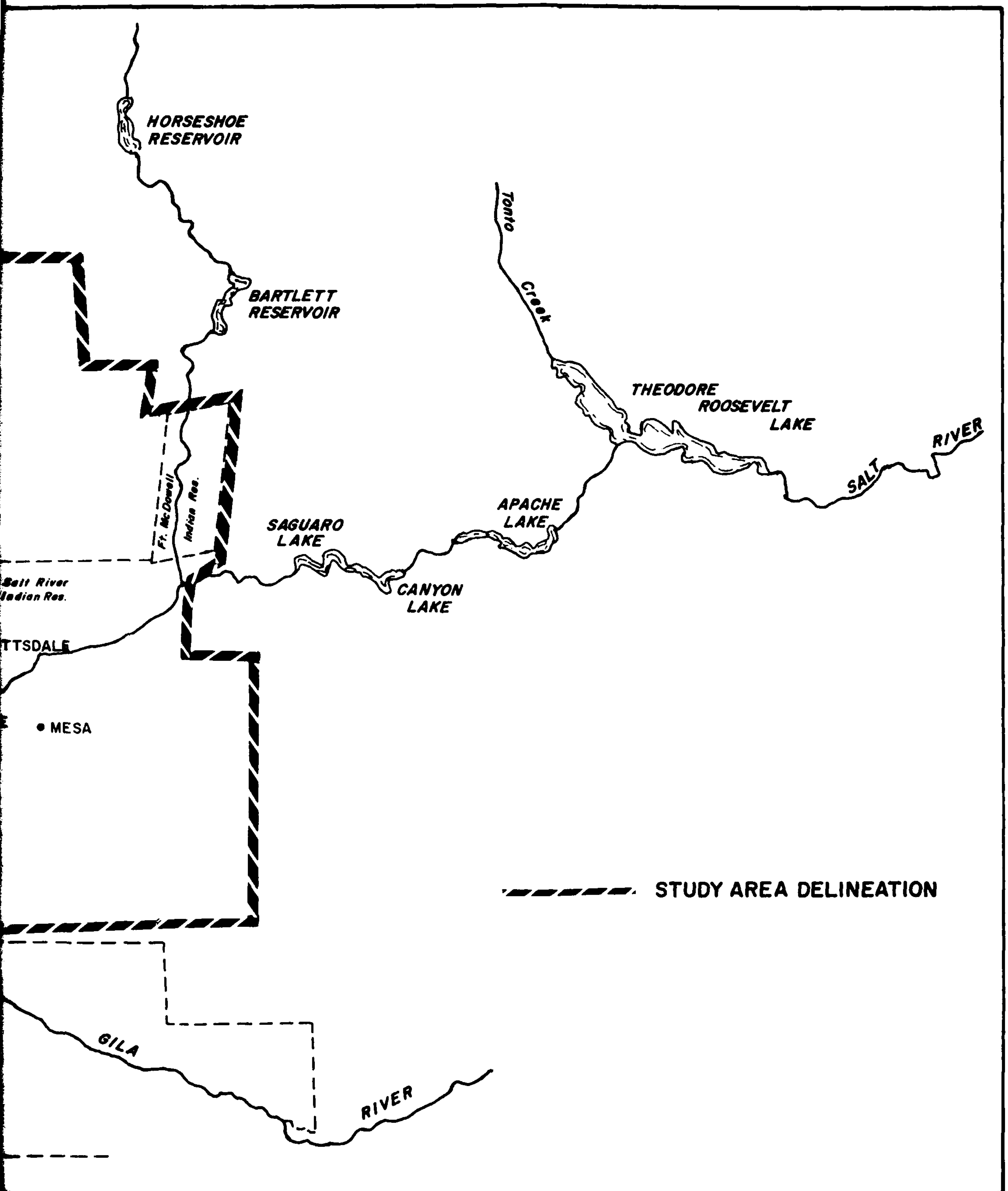


Figure I-1 STUDY AREA BOUNDARIES


HORSESHOE RESERVOIR
BARTLETT RESERVOIR
Tonto Creek
THEODORE ROOSEVELT LAKE
SALT RIVER
APACHE LAKE
SAGUARO LAKE
CANYON LAKE
Ft. McDowell Indian Res.
Salt River Indian Res.
TTSDALE
MESA
STUDY AREA DELINEATION
GILA RIVER

2

area delineation and the location of major reservoirs upstream with respect to the area under investigation.

The level of study detail is commensurate with Stage II planning of the Corps of Engineers (Corps of Engineers 1975). The detail varies due to the limited information availability at specific locations within the study area. Flood hazard and flood damage information provided by the District is considered preliminary due to limited availability of results from ongoing investigations. The findings of this document are intended for incorporation into a comprehensive report describing the feasibility of nonstructural measures for the CAWCS.

Material presented herein provides a definition of the present flood problems, describes the present institutional plan preparedness arrangements, presents scenarios of potential flood crises situations, and analyzes and formulates potential enhancements to existing flood preparedness arrangements and activities. The performance of the plan enhancements and the relationships of preparedness plans to other alternatives currently under investigation are presented. Appendix A provides references and Appendix B describes the flood damage evaluation procedures used in the study.

Summary of Findings

A serious flood threat presently exists throughout the study area. The threat is most serious to transportation and public facilities for events up to about the 50-year exceedance interval event. Consequences of an event of this magnitude are significant traffic disruption and congestion, damage to highways and bridges, and to a lesser degree damage to commercial businesses and private homes. The flood threat to the area from a quite large flood event, one exceeding the 100-year exceedance interval, could well be catastrophic with the metropolitan area divided with total loss of bridge crossings, crises develop in emergency services, catastrophic damage inflicted upon businesses and communities, and major social disruption generated from the displacement of many thousands of residents from their homes.

Flood emergency preparedness plans are growing in sophistication, utility, and acceptance across the United States as a viable means of mitigating the impacts of catastrophic flood events. Preparedness plans provide their greatest value in reducing the threat to life by adopting planned actions ready for implementation in times of

emergency. They also offer an opportunity to mitigate flood damage through such mechanisms as cooperative public flood fighting and assisting the individual in private damage mitigation activities. Flood preparedness plans aid in management of the impacts of flood events; they do not lessen the magnitude of the flood nor significantly lessen the hazard of an individual structure to flood damage.

A form of preparedness plans presently exists in the study area, stimulated through the unusual recent occurrence of several major flood events. Emergency response actions were quite successful in lessening the hazard to life. Actions to mitigate damage through temporary measures were few. Concern exists that the present relatively high state of awareness and preparedness will rapidly dissipate in the absence of floods unless specific action is taken to formalize arrangements and establish a plan for maintaining a state of readiness.

Since the recent floods, involved agencies have continuously improved and updated many aspects of the preparedness procedures within their technical and resources limitations. Coordination among agencies was found to be excellent. However, opportunities exist to further refine and increase the effectiveness of preparedness plans in the study area.

Opportunities to enhance existing preparedness arrangements were discovered through study of the local capabilities gathered through an extensive interview process, formulation and study of flood event senarios, detailed analysis of the flood threat and flood damage characteristics of the area, and study of a range of emergency action options.

Proposed enhancements are:

1. Modification of existing preparedness plans to base flood response actions on predicted water surface elevations instead of discharge.
2. Establishment of functional coordinators within the Emergency Operations Center based on present reponsibilities and authorities.
3. Streamlining and updating of arrangements for the collections of hydrometeorological data and information.
4. Modification and extension of arrangements for warning dissemination.

5. Increased development of detailed plans and procedures for:
   A. Evacuation of endangered areas;
   B. Flood fighting;
   C. Management of vital services;
   D. Recovery/reoccupation actions in the immediate post-flood period; and
   E. Continuous plan maintenance.

The enhancements are expected to contribute directly to improved communication and emergency actions management during flood emergencies, enhance long-term preparedness maintenance, and provide a positive opportunity for flood damage mitigation by implementation of selected temporary measures.

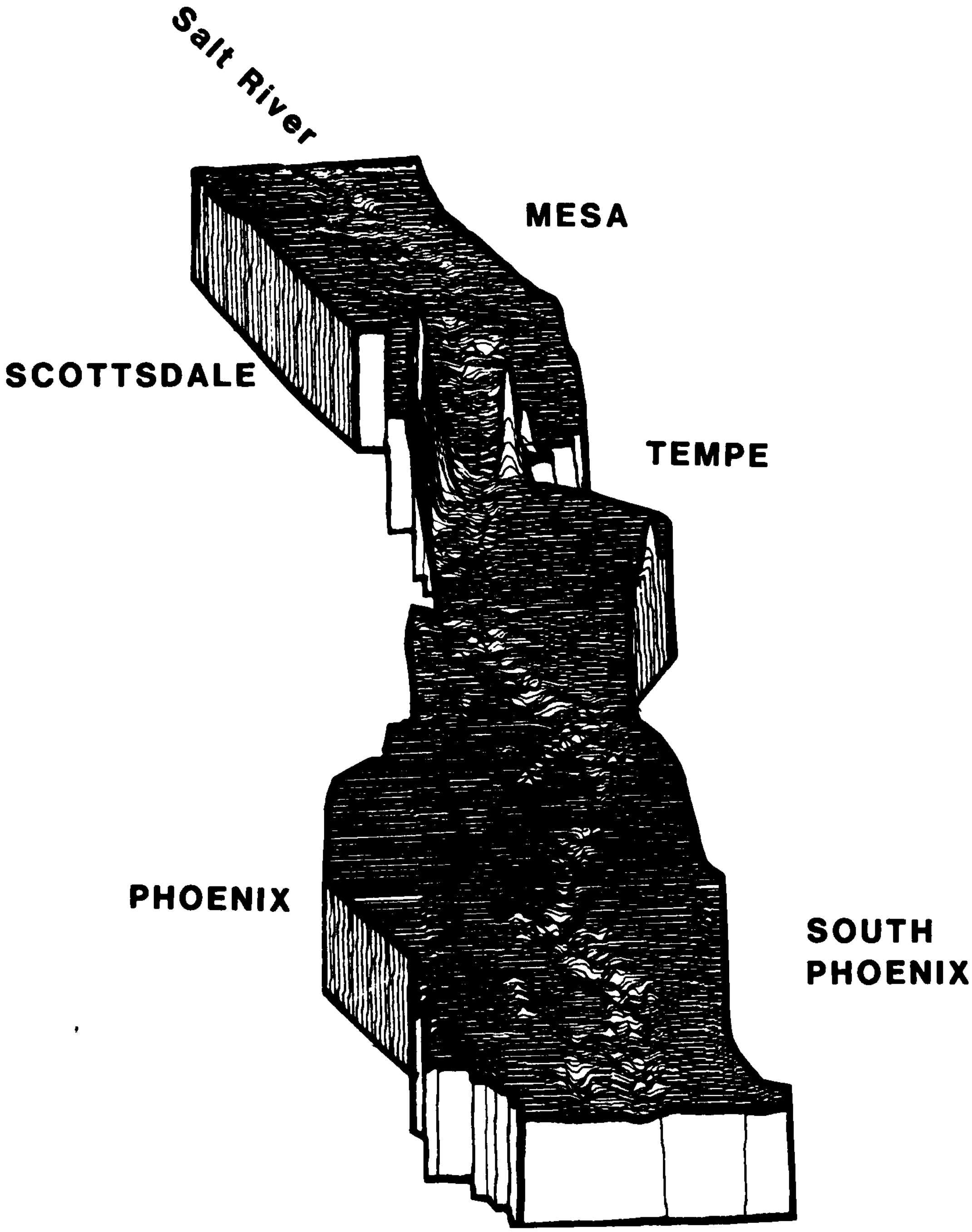


Figure II-1

TOPOGRAPHIC PERSPECTIVE OF SALT RIVER

CHAPTER II
DEFINITION OF FLOOD PROBLEM

Overview

The study area consists of a complex of communities and cities founded in the late 1800's. A primary concern of the metropolitan Phoenix area is municipal, industrial, and agricultural water supply. Surface water storage projects, groundwater sources and canal systems for water distribution are being developed to meet these needs. Availability of water, the general flat topography of the valley, and desirable climate have created significant development in recent decades. Figure II-1 illustrates the typical flood plain topography of the Mesa through Phoenix segment of the study.

Floods occuring between 1978 and 1980 have caused major damage to the flood plain areas of the Salt, Gila, and Agua Fria Rivers. The damage was primarily to public and private facilities with major social disruptions to businesses and services.

Nature of Floods

Flooding from the Salt, Gila, and Agua Fria Rivers in the study area is seasonally related to large regional storms and associated snowmelt that primarily occurs in winter and early spring. The problem is aggravated by the necessity to maximize upstream reservoir storage levels during this period to provide for water supply and hydroelectric power needs throughout the balance of the year. Reservoirs on the Salt and Verde Rivers (See Table II-1 and Figure I-1) were authorized and designed for water supply and hydoelectric power services for the Salt River Project (SRP) authority. Management of reservoir storage for these conservation services conflicts with alternative management that would emphasize flood control. For example, one might typically manage the system to within about 85 percent of the total storage capacity prior to mid-January to assure adequate water supplies during the spring and summer heavy demand periods.

The potential for reservoir spillages and downstream floods are the greatest after the winter storm season and prior to the reduction of storage levels in the spring and summer. Figure II-2 displays the monthly distribution of Salt River floods. The figure indicates that 90 percent of historic flooding has occurred in the months of January through April with none having occurred during the months of June through October.

TABLE II-1

RESERVOIR DATA (LOS ANGELES DISTRICT, 1975)

River	Dam Name	Lake Name	Drainage Area Above Reservoir (Sq. Mi.)	Storage Capacity (Acre-Ft.)
Salt	Roosevelt	Roosevelt	5,830	1,381,580
	Horse Mesa	Apache	5,940	245,138
	Mormon Flat	Canyon	6,100	57,852
	Stewart Mountain	Saguaro	6,220	69,768
Verde	Horseshoe	Horseshoe	5,970	139,278
	Bartlett	Bartlett	6,160	178,500
Agua Fria	Waddell	Pleasant	1,450	163,000
		TOTAL	13,840	2,235,116

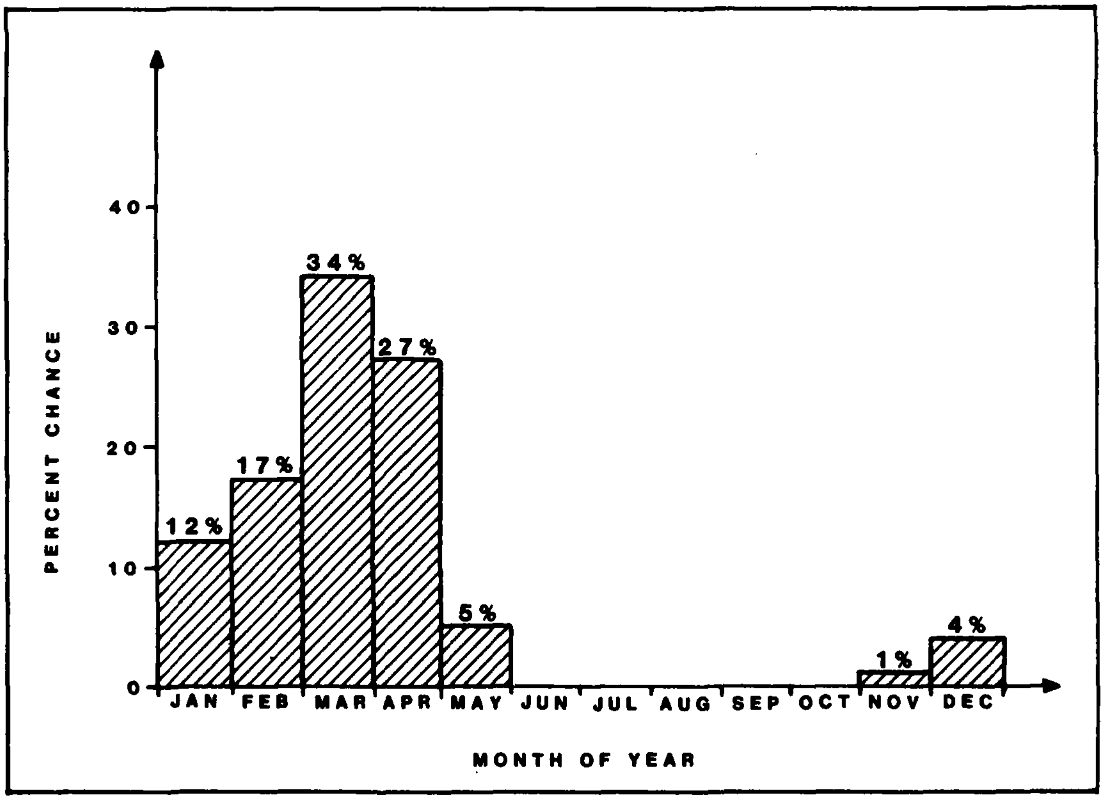


Figure II-2 MONTHLY DISTRIBUTION OF SALT RIVER FLOODS

Water supply and and hydroelectric power generation releases are subsequently diverted at Granite Reef Dam into distribution canals along the north and south sides of the Salt River. During flood crises situations; SRP operates the reservoir system to mitigate downstream losses, to the extent possible within the constraints of their authority and physical facilities. The effectiveness of this operation is based upon the early recognition of a potential for spillage, the storage capacity levels of the reservoirs, and the nature of the flood runoff entering the system (timing, magnitude, volume, and spatial distribution) within the Salt River basin. Operation in this manner has attenuated downstream flood peaks of historic events from 2-50 percent (Los Angeles District 1980a).

The flood plain through the metropolitan Phoenix area is alluvial with continuous aggregation and degradation occurring (sometimes significantly) between and during flood events. Channel alignments may also be altered. Accurate flood predictions are difficult to make because events of similar magnitudes often yield different flood elevations and inundation areas.

During major events, flood transported sediments are deposited in the pools of the upstream reservoirs, thereby increasing the sediment transport capacity of flows downstream of the reservoirs. The sediment carrying capacity is likely to be further increased by the cold water temperatures of floods containing melted snow. These conditions typically result in a degradation of the main conveyance system through Mesa, Tempe, and Phoenix during major flood events, with deposition occurring along the slower velocity overbank areas, particularly downstream of Phoenix and the confluence of the Gila River.

Sediment accumulation and natural encroachment of the conveyance system occurs during dry periods. Sediment deposits in the major channel occur from flash floods in small tributary streams and washes below the reservoirs, low flow releases, and developmental disturbances. Salt cedars and overbank growth encroach upon the channel resulting in reduced conveyance capacity and rougher channel and overbank areas. Major floods which happen after substantial periods of low or no flow conditions in the main channel can expect to be more severe (higher elevations for the same discharge) due to increased roughness and reduced channel capacity. Similar circumstances occur along the Gila and Agua Fria Rivers as described for the Salt River.

Historic Flood Events

Direct flooding from the Salt, Gila and Agua Fria Rivers in the Phoenix metropolitan area has occurred only periodically, with substantial periods of time often elapsing between major flood events. During the 58-year period from 1920 to 1978, only one significant event (95,000 cfs in 1938, or approximately a 10-year frequency event) occurred on the lower Salt River. Throughout this period, the river remained essentially dry, often for substantial periods (such as 1941-1965). Commensurate with this dry period was the rapid growth and development of the area which continues today. Lack of awareness of a potential flood threat, or in many instances the existence of a riverbed itself, have resulted in flood plain encroachments and development practices that have greatly increased the damage potential in the study area. Converse of this relatively dry period has been the recent occurrence of three major events (March 1978, December 1978 and February 1980). These floods disrupted social services and significantly damaged portions of the study area resulting in extensive damages to public facilities (bridges, airport runway, roads, etc.), and private and personal property.

Flood Hazard Analyses

Flood hazard analyses were performed to increase knowledge of flood characteristics, provide input for flood damage evaluations at damage reach index locations, and assist in determining potential flood impact to important community services. Analyses included development of discharge frequency relationships and rating functions (discharge-stage relationships).

Discharge-frequency relationships at selected locations were developed by period-of-record analysis (1889-1979) performed by the Los Angeles District for the Salt River system. Table II-2, shows the discharge-frequency functions at selected study control points throughout the study area. The reduction in peak discharge proceeding downstream reflects attenuation of flood peaks due to natural storage in the Salt River flood plain.

Travel times of peak discharges throughout the Salt River study area were also determined from the investigation (Corp of Engineers 1980c) and are listed in Table II-3. The values represent estimates of relative differences in warning time between Gilbert Road and the downstream areas. For example, the warning time for emergency

TABLE II-2

DISCHARGE-FREQUENCY RELATIONSHIPS
(LOS ANGELES DISTRICT 1980b)

Salt River Location	5-Year	10-Year	20-Year	50-Year	100-Year	200-Year	500-Year
Below Granite Reed Dam	45,000	102,000	141,000	175,000	245,000	290,000	360,000
Gilbert Road	44,000	100,000	139,000	170,000	230,000	285,000	345,000
Tempe Bridge	40,000	93,000	135,000	160,000	215,000	275,000	330,000
Central Avenue	39,000	91,000	130,000	155,000	200,000	265,000	325,000
67th Avenue	38,000	90,000	126,000	150,000	190,000	255,000	315,000
115th Avenue (above confluence with Gila River)	36,000	85,000	125,000	145,000	185,000	250,000	310,000

TABLE II-3

ESTIMATED FLOOD WAVE
TRAVEL TIMES FROM GRANITE REEF DAM
(LOS ANGELES DISTRICT 1980c)

Location	Travel Time (Hrs.)
Gilbert Road	2
Tempe Bridge	6
Central Avenue	10
67th Avenue	12
115th Avenue	13

response actions in the vicinity of Central Avenue would be approximately 8 hours greater than Gilbert Road.

Flood discharges associated with closure of the numerous crossings over the Salt and Gila Rivers are of paramount interest to the people in the study area. Dip crossings are closed at discharges from zero to 5,000 cfs with closures of bridges at higher discharges. Table II-4 shows existing and planned design capacities of Salt and Gila River crossings. The table indicates that no bridge would be expected open for discharges greater than 200,000 cfs either now or in the planned for future. This corresponds to an event that would be expected to occur about once every 100 years on the average.

Water surface profile analyses for the Salt and Gila Rivers were performed by the Los Angeles District. Results were used primarily to develop rating functions at damage reach index locations and to delineate flood inundation boundaries for selected events and conditions. Because of the alluvial nature of the rivers, it should be stressed that these analyses represent only one point in time corresponding to the conditions existing when the stream geometric data were gathered (fall of 1977). The profiles are expected to change both during flood events and in the long-term.

Velocities of flood flows for the hundred year event are expected to range from 6-15 feet per second in the main channel and 1-4 feet per second in overbank areas. Velocities exceeding three feet per second and depths of flooding over three feet are considered hazardous.

Figure II-3 displays estimated depths of flooding from the occurrence of a 100-year event for the reach from Mesa through Phoenix. The display was generated using procedures described in Appendix B. Water surface profiles and flood specific flood inundation boundaries of the rivers under investigation are provided in subsequent reports of the Central Arizona Water Control Study.

Flood Damage Analysis

Overview. Flood damage analysis was performed to identify potential damage locations, the type of damage, and the damage reduction associated with implementing temporary flood mitigation measures to individual residential, commercial and industrial

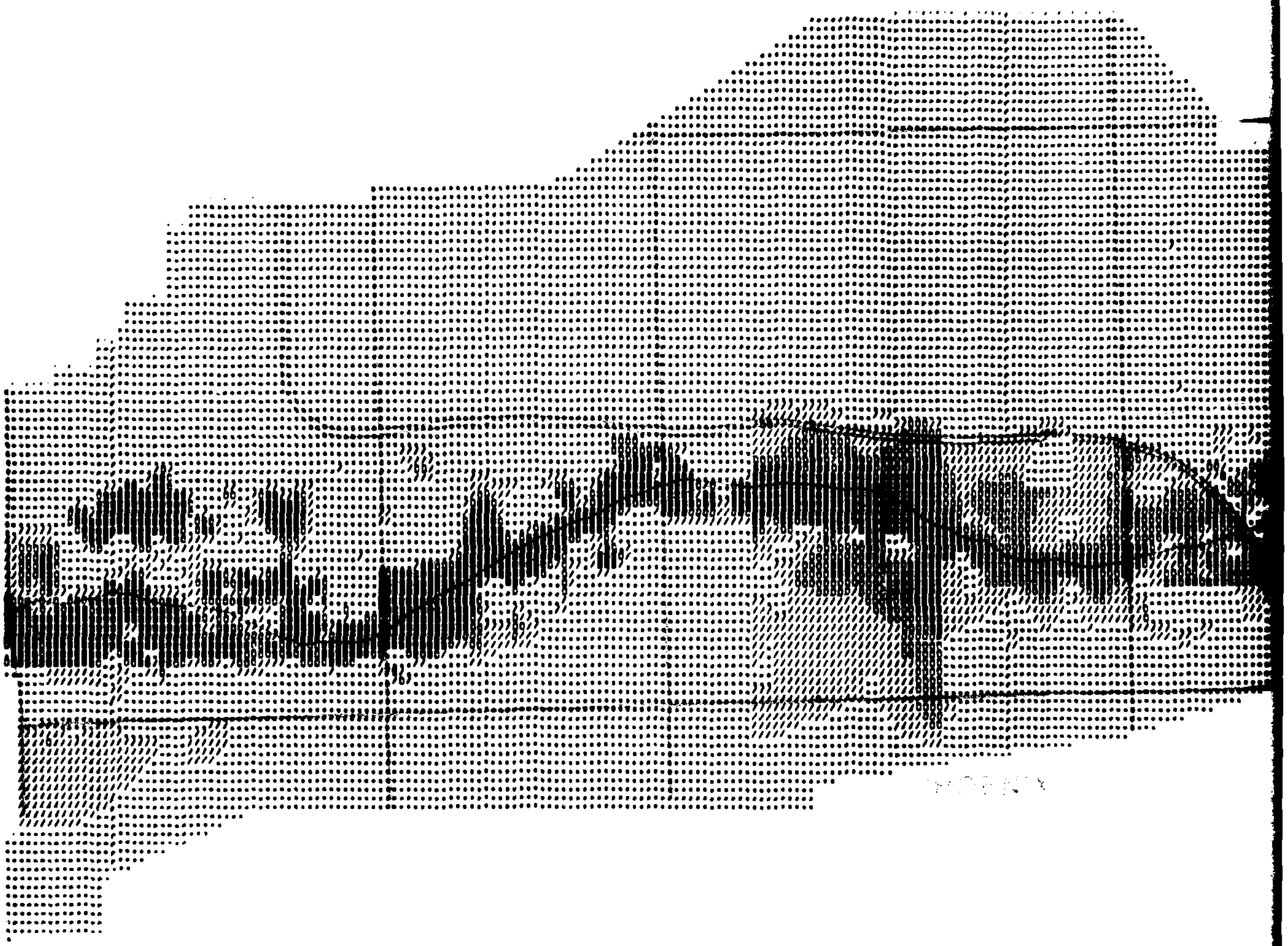
TABLE II-4

EXISTING AND PLANNED DESIGN CAPACITIES
FOR SALT AND GILA RIVER CROSSING
(LOS ANGELES DISTRICT 1980d)

Location	Capacity (cfs)	Location	Capacity (cfs)
Gilbert Road	0-5000	Central Avenue	220,000
Country Club	200,000*	7th Avenue	25,000
McKellips Road	0-5000	19th Avenue	180,000*
Alma School Road	200,000*	35th Avenue	35,000
Dobson Road	None	51st Avenue	200,000
Pima Road	10,000	67th Avenue	0-5000
Hayden Road	0-5000	91st Avenue	0-5000
Scottsdale Road	200,000	115th Avenue	0-5000
Mill Avenue	170,000	123rd Avenue	0-5000
48th Street	0-5000	Bullard Road	0-5000
Hohokam Expressway	15,000	Tuthill Road	200,000
40th Street	13,000	Rainbow Valley Road	None
I-10 Freeway	170,000	Airport Road	0-5000
24th Street	200,000*	Miller Road	0-5000
16th Street	200,000*	Highway 85 (Buckeye)	33,000
7th Avenue	15,000	Gillespie Dam (Old US 80)	135,000

*Planned for implementation by end of 1982.

structures. Geographic information (spatial gridded data) processing and analysis procedures formed the basis of the damage evaluation methods. Appendix B describes these procedures. Geographic information sets, in the form of a grid cell data bank, were provided by the Los Angeles District. Analyses were not performed for the Agua Fria River because of information limitations at the time of the investigation. Flood damage assessments and associated information presented herein is limited to that considered essential for this investigation. Damage information presented should not be interpreted as definitive of the final economic analysis that are presented in other reporting documents of the comprehensive Central Arizona Water Control Study.



LEGEND

:: NO FLOODING

// DEPTH OF FLOODING 0 TO 3 FEET

88 DEPTH OF FLOODING 3 TO 6 FEET

|| DEPTH OF FLOODING OVER 6 FEET

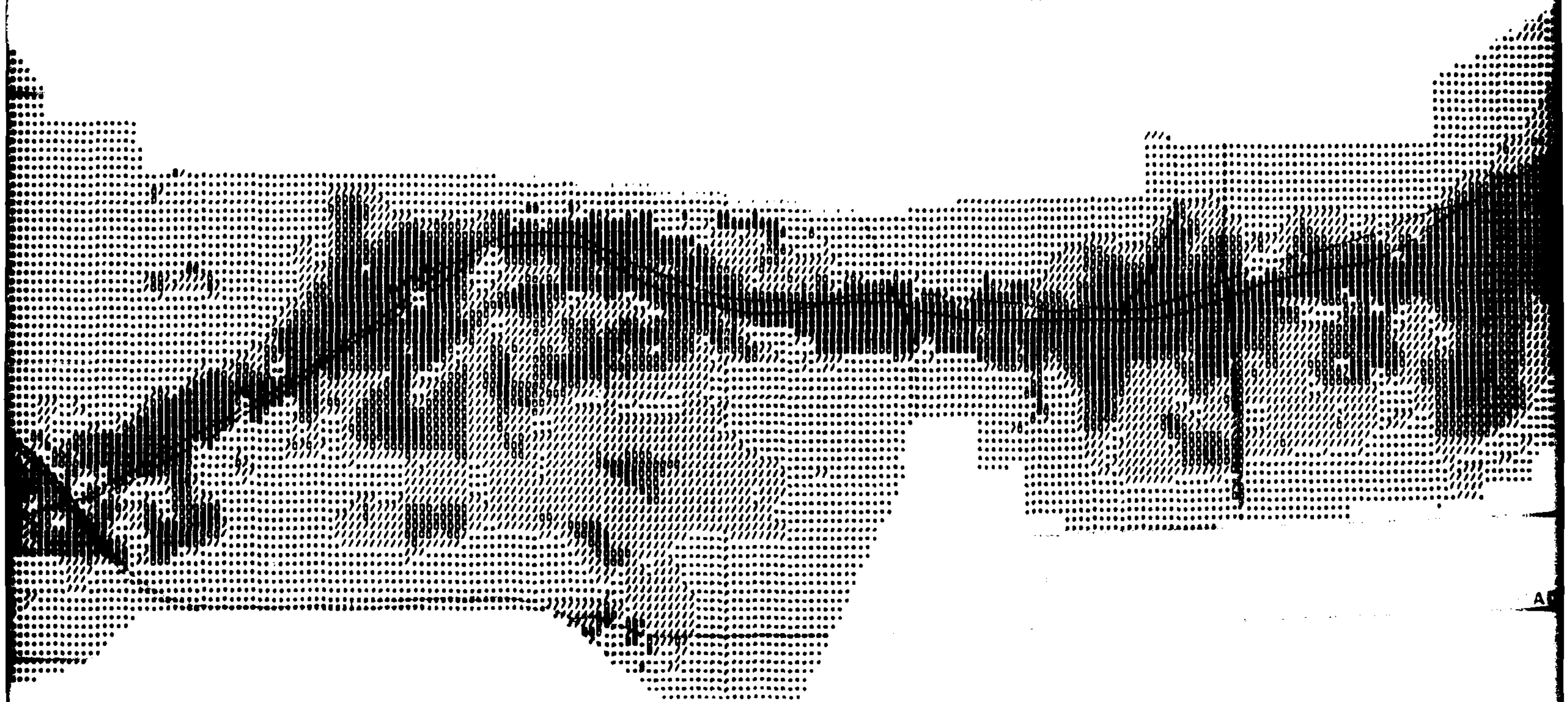


Figure II-3 100-
MAP:

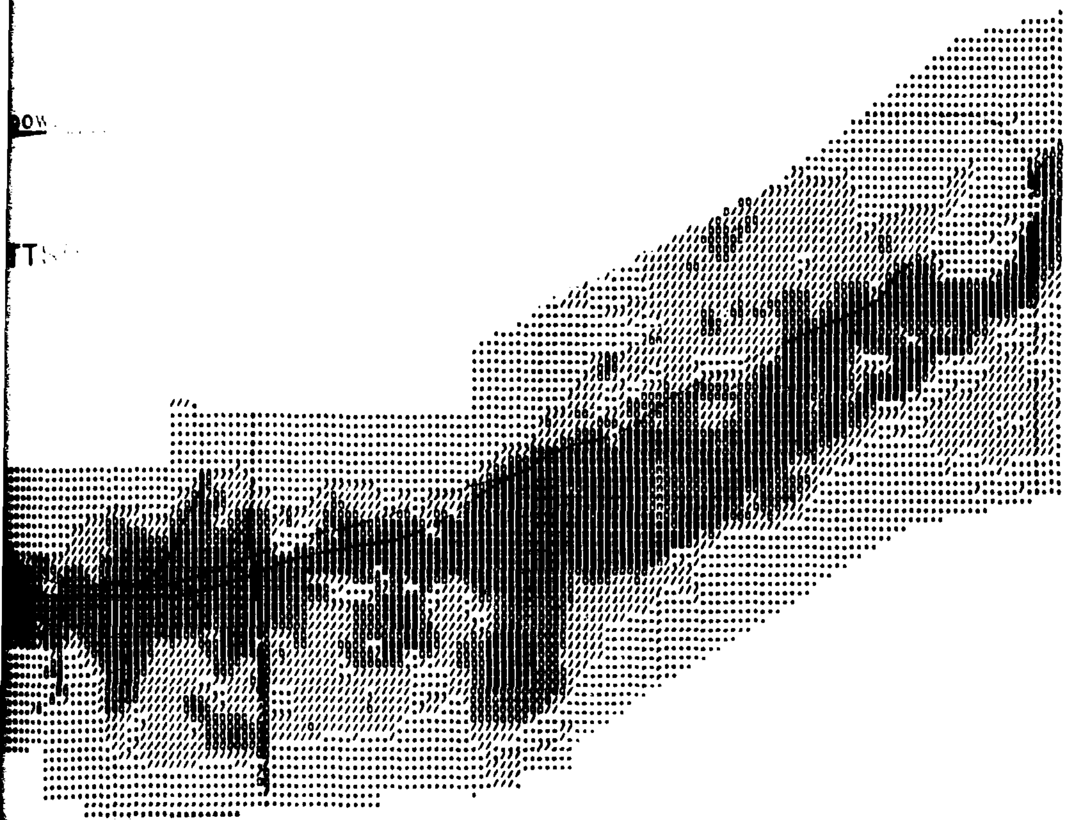


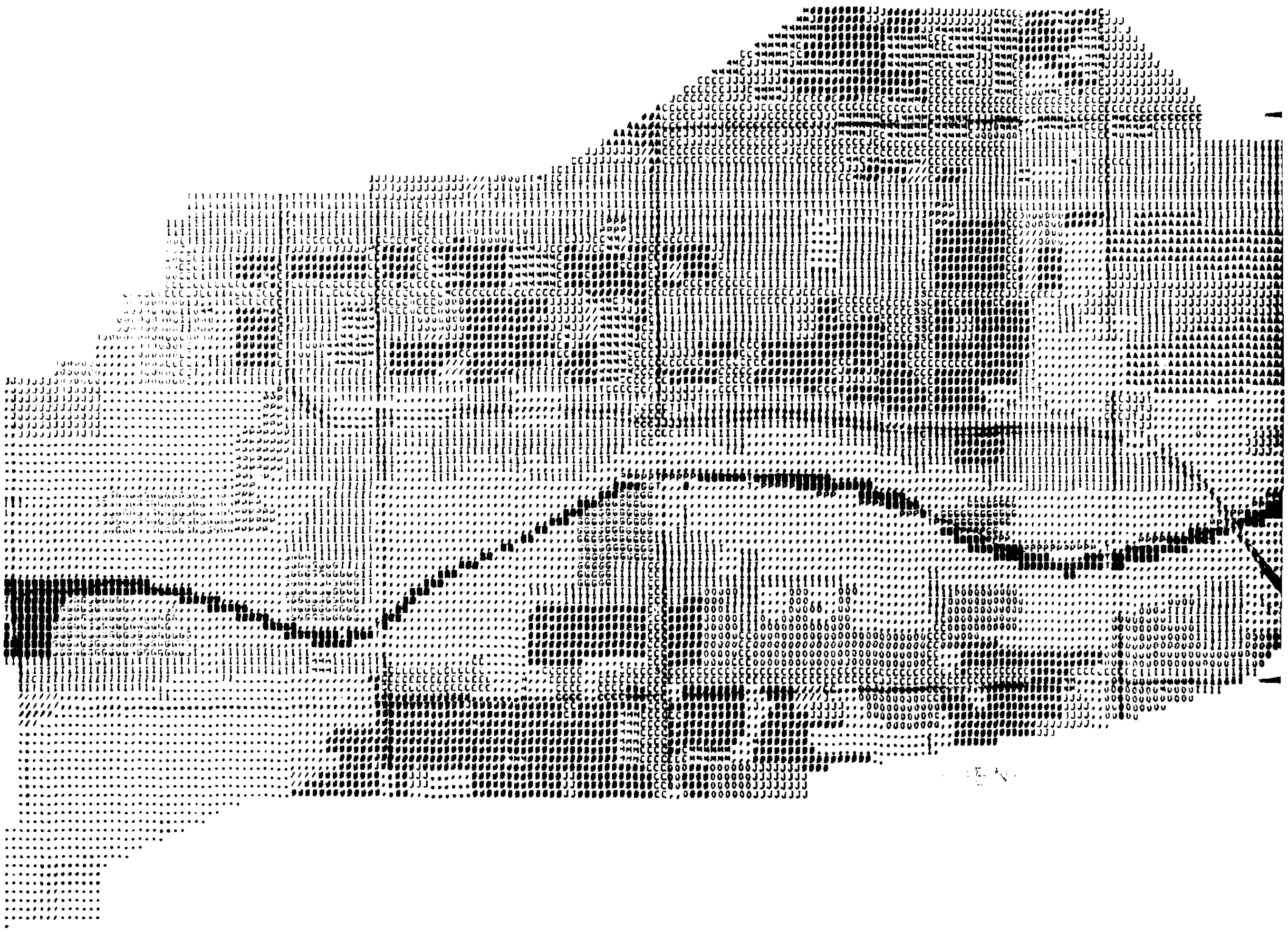
Figure II-3 100-YEAR DEPTH OF FLOODING MAP: MESA THROUGH PHOENIX

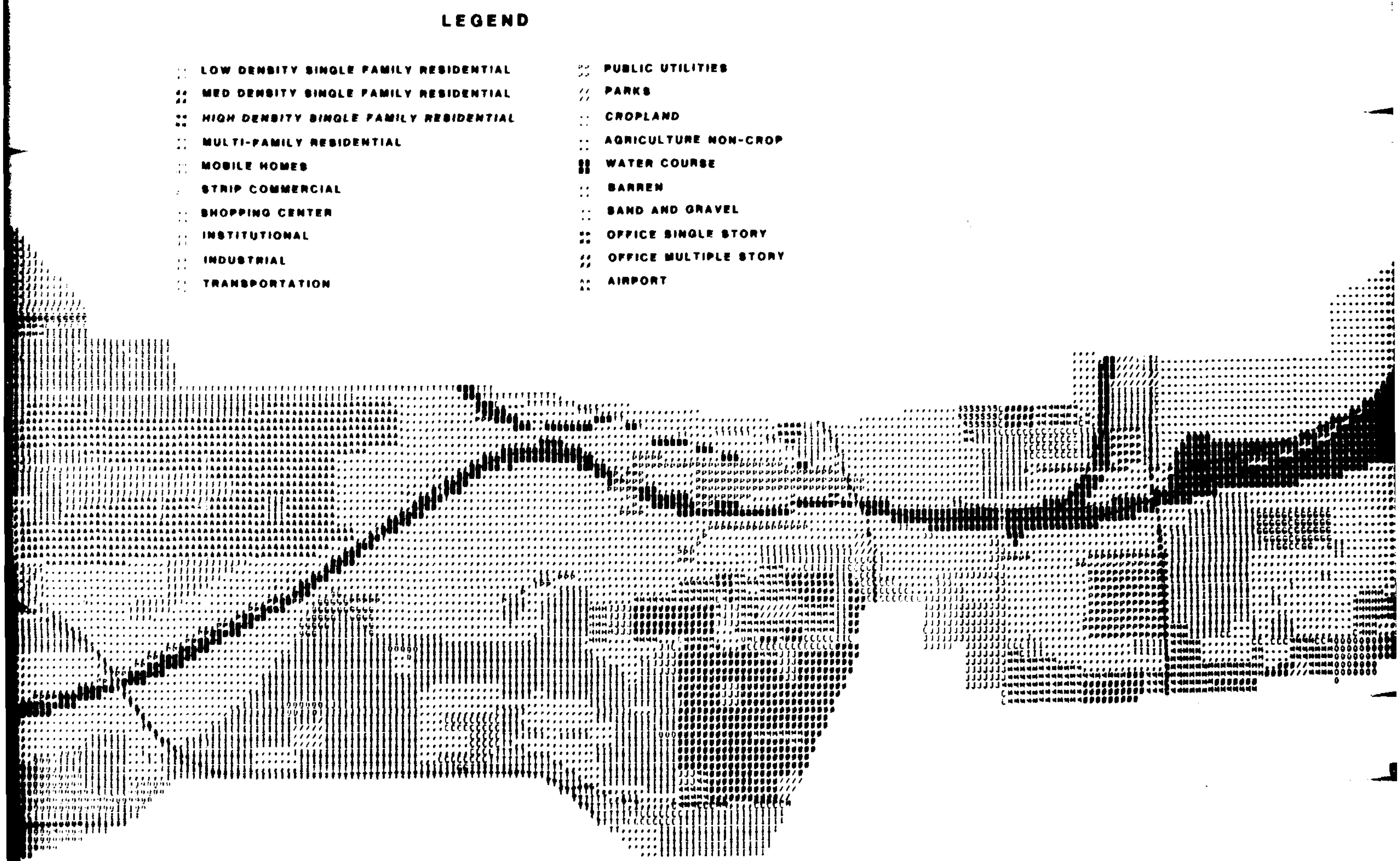
The Salt-Gila study area (Mesa to Buckeye) was delineated into 16 damage reaches for analysis purposes. Reach delineations were based on consistency in water surface profile sets and community jurisdictional boundaries. Damage calculations were performed for each damage category and reach. Figure II-4, displays the land use definition for Mesa through Phoenix. Calibration of data and assumptions were made to approximate values attributed to the March 1978 and December 1978 floods. Adjustments were made to land use density and vacancy factors (see Appendix B) until the percent of damage by general classification, number of structures inundated, and damage totals were similar to those of the two historic events.

The analysis provided information of damage potential and possible enhancements to present preparedness plans. The information developed centered about: estimates of the potential number of residential, commercial, and industrial structures inundated at various flood levels; type and location of existing conditions damage; and damage reduction associated with implementation of temporary flood mitigation measures (perimeter barriers, content adjustments, etc.). The analyses were performed for the 16 damage reaches which were subsequently aggregated into four reaches to simplify display of the results. The four reaches divided primarily along jurisdictional boundaries, are Mesa, Tempe, Phoenix, and 35th Avenue to Buckeye.

Reach Summaries. The number of structures at or below specific water surface elevations were derived from automatically generated elevation-area tables for each damage category. Existing condition damage values were calculated for single events based on specified water surface elevations and aggregated elevation-damage relationships by categories at the damage index locations. A graphic of the relative damage values for residential, commercial and industrial categories associated with the 50-, 100- and 500-year events for the Mesa to Phoenix reach is shown in Figure II-5. A significant increase in damage potential occurs between the 100- and 500-year events. The spatial location of the damage potential is also important, with the highest concentration occurring in the Tempe and Phoenix areas.

Damage Reduction by Temporary Emergency Measures. Analyses of temporary flood mitigation measures were conducted to assist in determining the economic feasibility of implementing such measures for individual structures as part of preparedness actions during flood crises situations. Measures investigated included perimeter barriers (floodproofing) and adjustment of contents (raising or removal).





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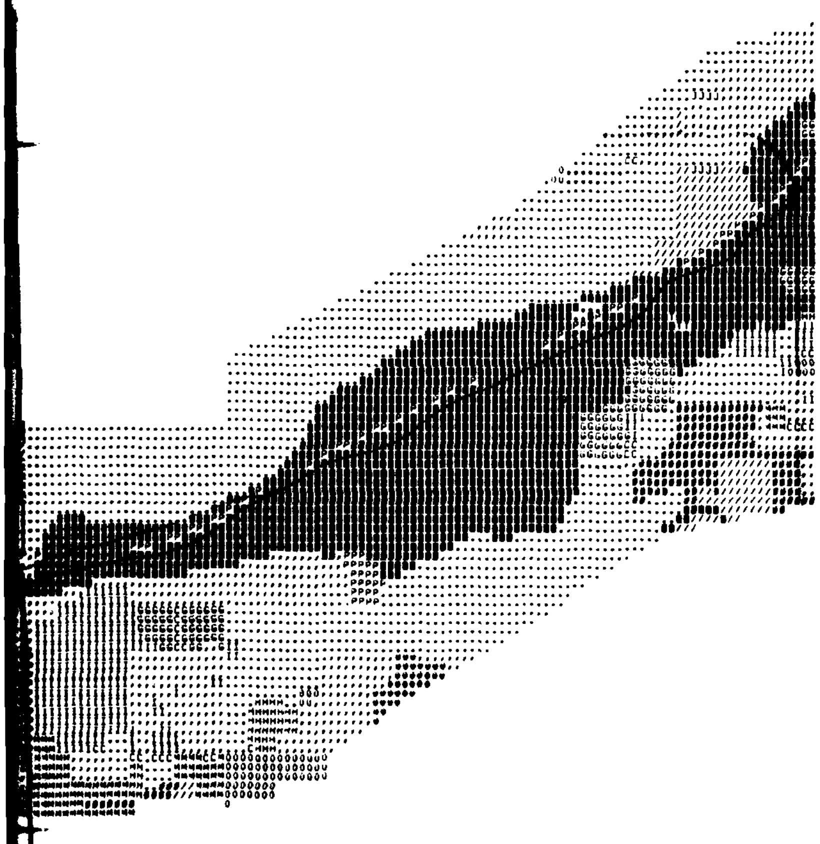
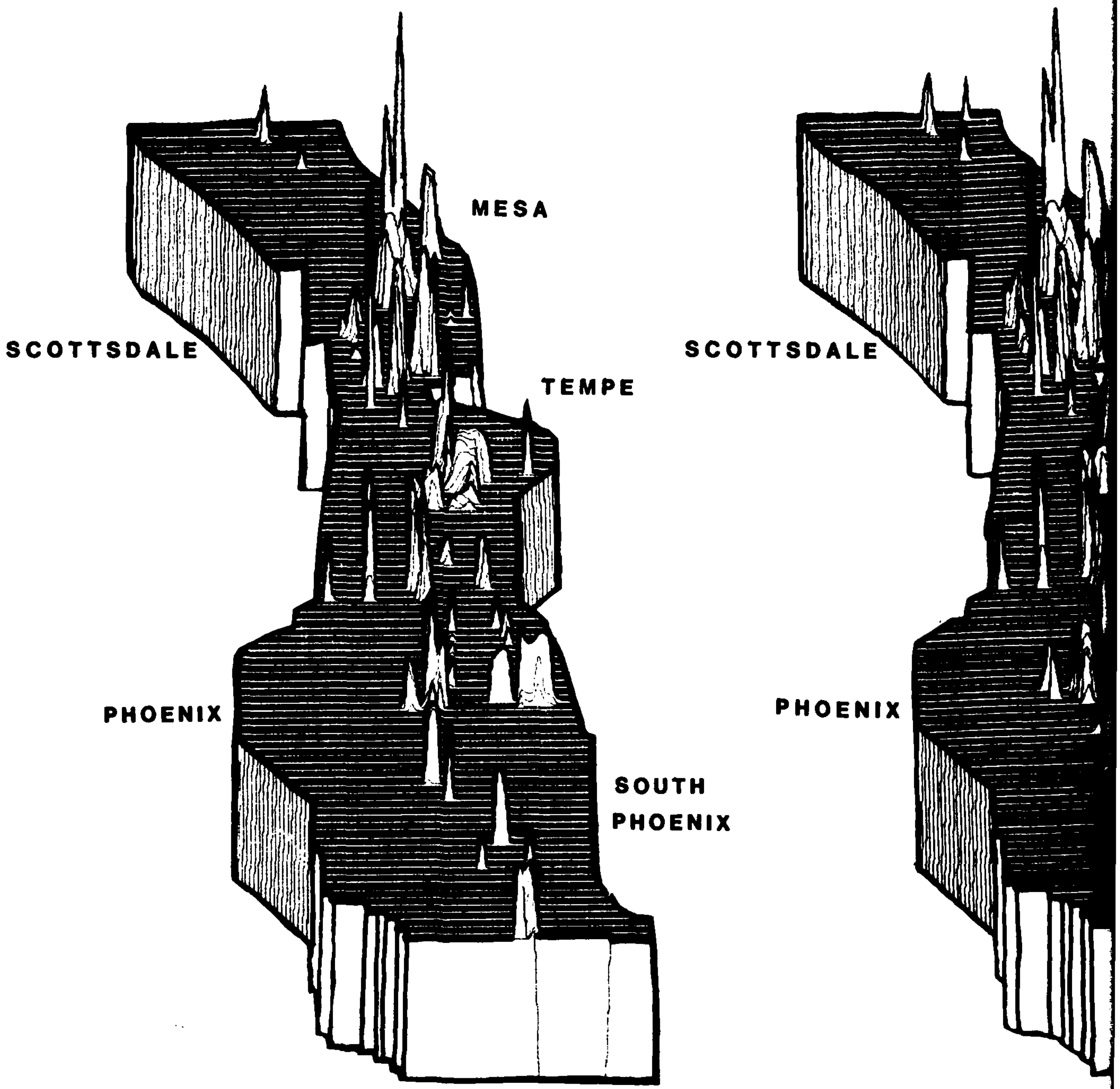


gure II-4 EXISTING LAND USE:
MESA THROUGH PHOENIX



50-YEAR EVENT

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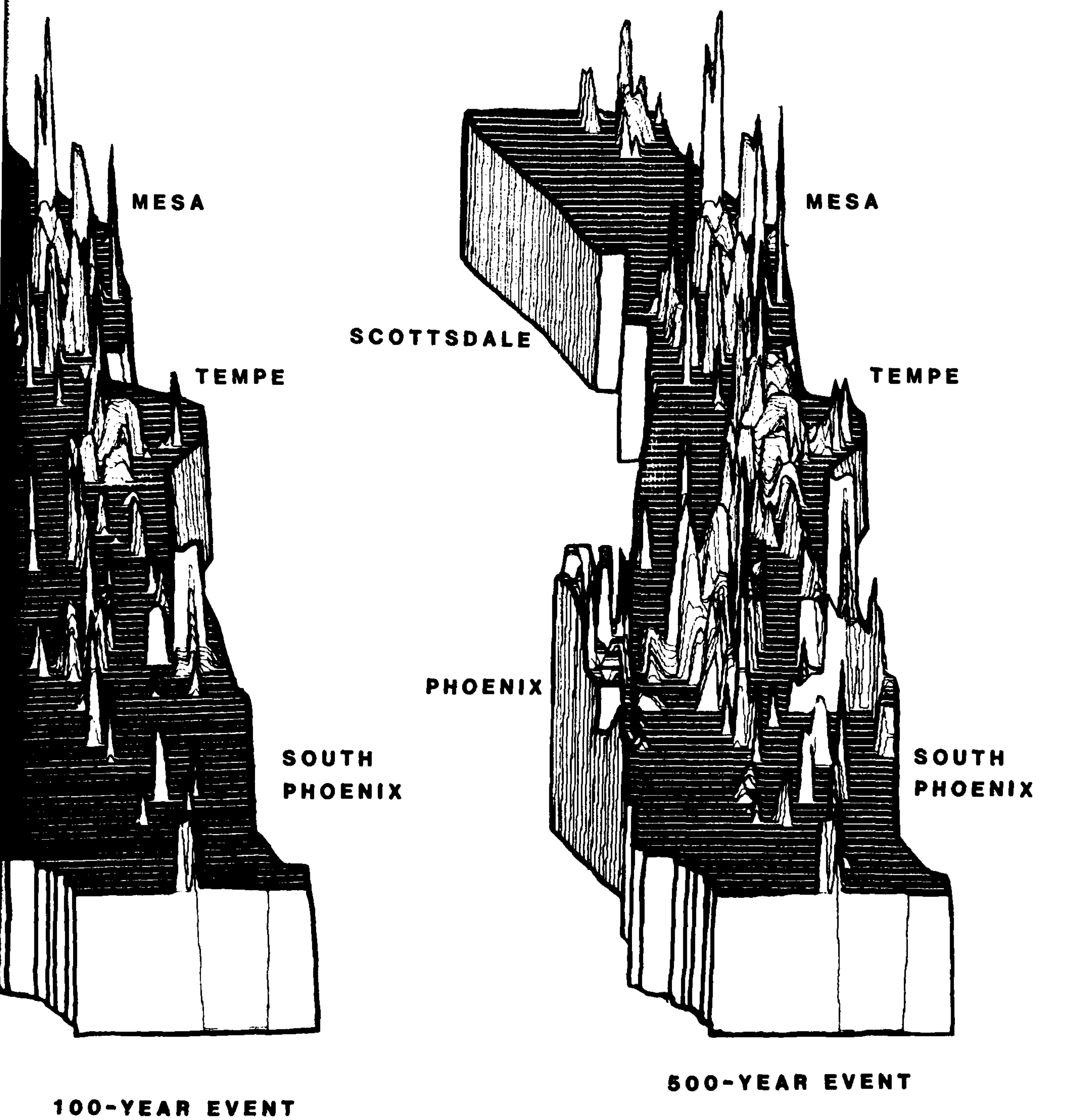
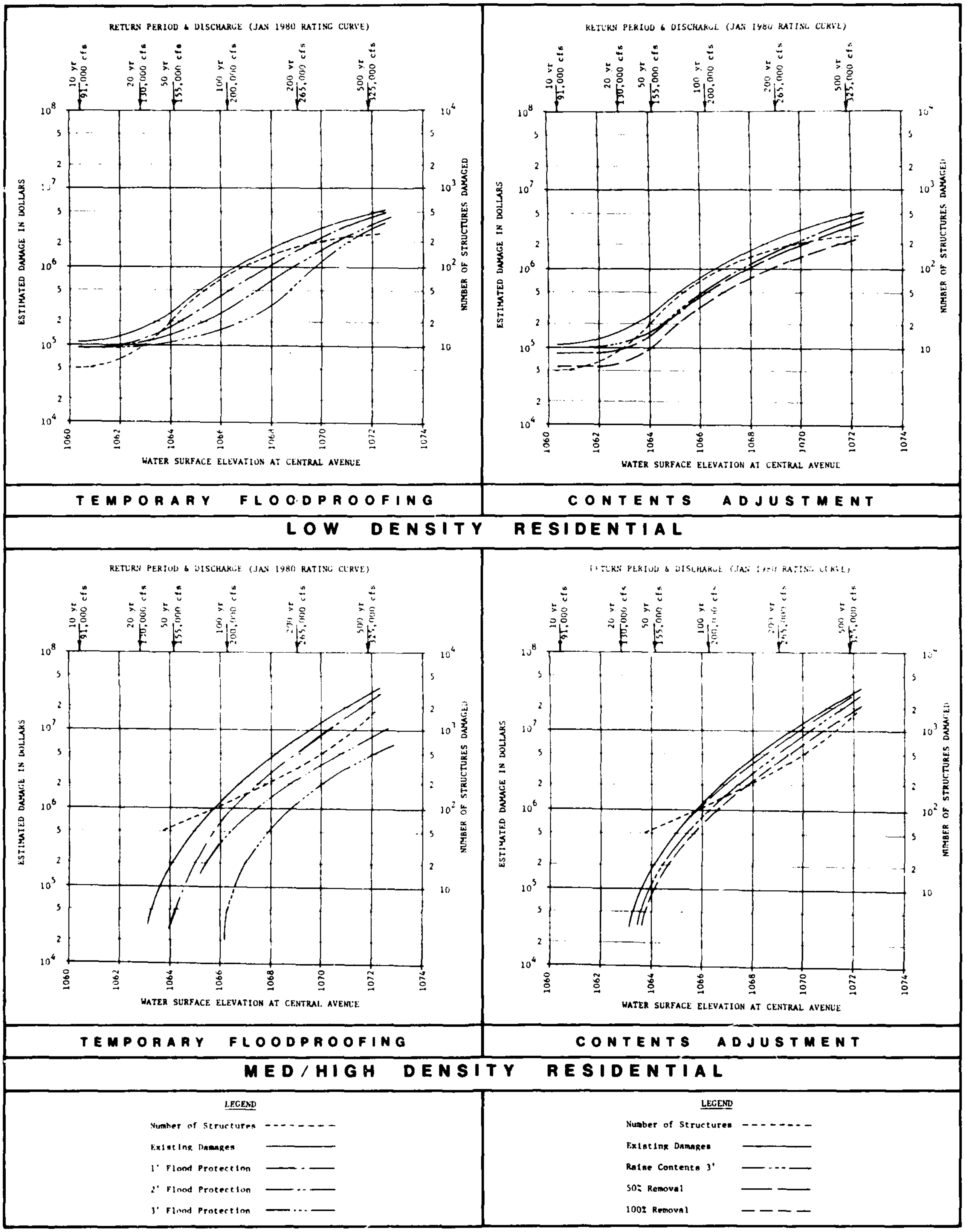


Figure II-5

EVENT DAMAGE PERSPECTIVE:

MESA THROUGH PHOENIX



PHOENIX REACH, RESIDENTIAL (48th Street - 35th Avenue)

Figure II-7 DAMAGE REDUCTION OF TEMPORARY MEASURES

Temporary perimeter barriers include small earth dikes, flashboard, sand bags, and polyethylene. Evaluations were performed for 1, 2, and 3 feet levels of protection for each structure. No attempt was made to determine the time requirement of implementation nor the effectiveness of such measures during this phase of the investigation. Content adjustment analyses were performed for 50 and 100 percent removal and raising 85 percent of the contents 3 feet. Figure II-6 displays the depth damage relationships for existing conditions, two feet protection of perimeter barrier, 100 percent removal of contents and raising of 85 percent of contents 3 feet. Graphic results of elevation-damage relationships for installation of temporary perimeter barriers and content adjustments to individual low density residential, medium/high density residential, commercial and industrial structures in the Phoenix reach are displayed in Figure II-7.

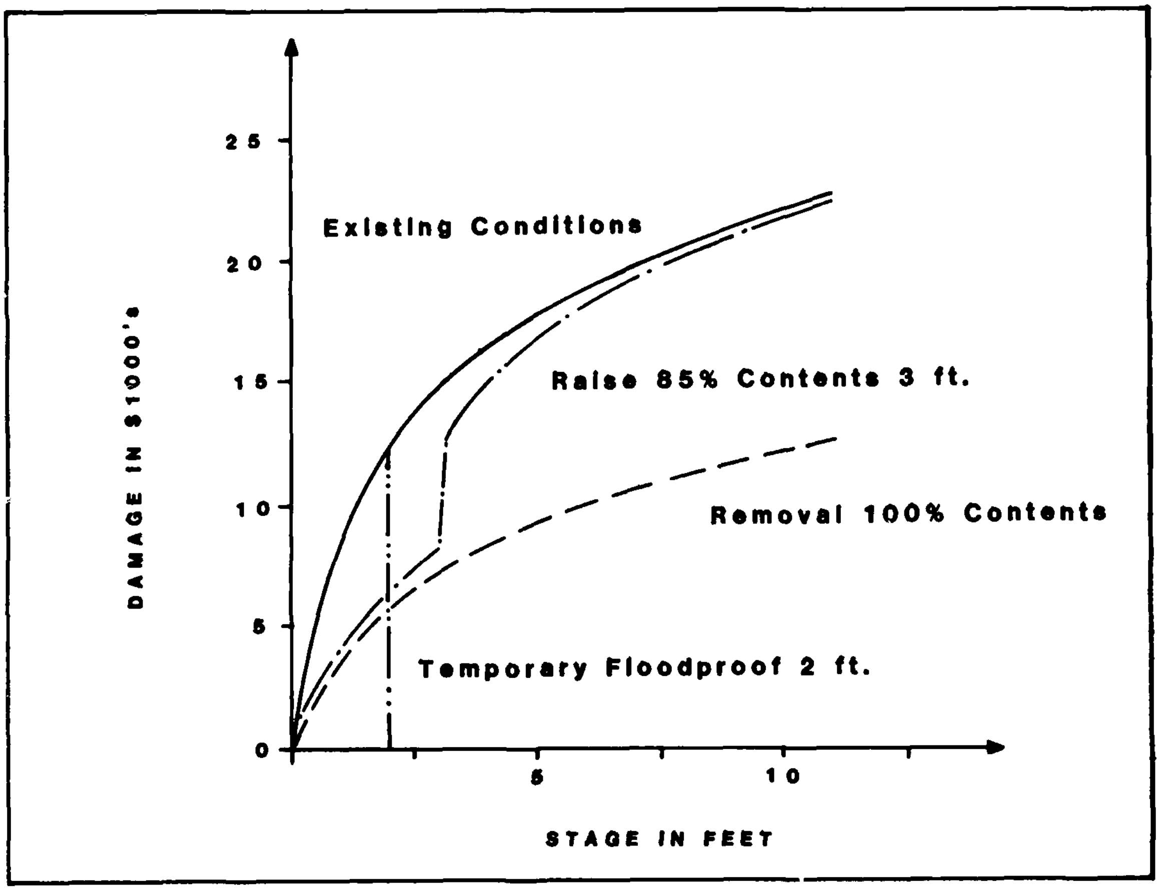


Figure II-6 STAGE-DAMAGE RELATIONSHIPS MESA THROUGH PHOENIX

An example demonstration use of the preceeding material is presented below to hopefully stimulate the reader to serious study of the range of the temporary measures and actions that can be investigated in a preliminary manner. Using the Phoenix reach as the example, the occurrence of a 100-year flood event would inundate approximately 120 medium/high density residential structures (Figure II-7). The corresponding total damage to medium/high density residential structures if no preventive actions were taken is estimated to be $1.4 million dollars or an average of $11,700 per this type of structure in the Phoenix reach. If effective temporary perimeter barriers were implemented for each structure the estimated total damage would be $500,000 to medium/high density structures or about $4,200 per structure. The difference in damage between no action and implementation of temporary barriers is about $7,500 ($11,700-$4,200) per structure, which represents the maximum justified cost for temporarily implementing a two foot high perimeter barrier.

Similar calculations may be performed for removal and raising of contents. Residual damages after removal of 100 percent of the contents would be about $750,000 (medium/high density residential, Phoenix reach) or an average of $6,250 per structure. This would represent a reduction in damage of about $5,450 ($11,700-$6,250) per structure. Other estimates of percent content removal would be directly proportional to this value. The average damage reduction per structure associated with raising 85 percent of the contents 3 feet is estimated to be $3,300 from Figure II-7.

The example demonstrates that significant damage reduction can be obtained for typical medium/high density residential structures in Phoenix by implementing effective temporary flood mitigation actions for the 100-year flood event. Similar calculations may be performed on an event basis for other residential, industrial, and commercial structures and reaches. Indications are that rather significant investments are justified for such measures on an event basis for moderate to rare floods. Removal of valuable contents and most certainly raising of contents would always appear to be prudent. Large scale content removal would depend upon adequate transportation, storage facilities, and protection assurances. Costs associated with these activities may be significant.

Calculation of expected annual damage associated with each of the temporary flood loss reduction measures was also performed as part of the damage evaluation process. The results provide some insights as to the effectiveness of the temporary measures in

reducing flood losses. Table II-5 lists the calculated values. Displayed values are predicated on the assumption that the measures were 100 percent effective until the event exceeded the protective levels.

TABLE II-5

EXPECTED ANNUAL DAMAGE
TEMPORARY MEASURES IMPACTS ($1000's)

Reach		Damage Category	Existing Conditions	Perimeter Barriers 1-ft. High	Perimeter Barriers 2-ft. High	Perimeter Barriers 3-ft. High	Content Adjustments 50% Removal	Content Adjustments 100% Removal	Content Adjustments Raise 85% 3 ft.
MESA	1.	Low Den. Res.	12	3	3	2	9	5	7
	2.	Med./High Res.	9	3	0	0	6	3	4
	3.	Commercial	2	1	0	0	2	1	2
	4.	Industrial	16	14	13	10	12	6	15
TEMPE	1.	Low Den. Res.	0	0	0	0	0	0	0
	2.	Med./High Res.	112	62	24	9	80	50	68
	3.	Commercial	210	204	201	194	167	126	206
	4.	Industrial	890	866	776	642	574	258	807
PHOENIX	1.	Low Den. Res.	46	38	29	23	34	23	37
	2.	Med./High Res.	62	35	21	11	46	30	41
	3.	Commercial	107	78	44	36	85	63	97
	4.	Industrial	522	508	454	385	345	164	477
35th Avenue BUCKEYE	1.	Low Den. Res.	208	145	88	43	139	80	138
	2.	Med./High Res.	202	146	88	37	142	82	139
	3.	Commercial	8	5	2	1	6	4	7
	4.	Industrial	48	44	32	20	31	14	38
TOTALS BY DAMAGE CATEGORY	1.	Low Den. Res.	266	186	120	68	182	108	170
	2.	Med./High Res.	385	246	133	57	272	165	252
	3.	Commercial	327	288	247	231	260	204	312
	4.	Industrial	1476	1422	1275	1057	962	442	1337
TOTAL DAMAGE			2454	2142	1775	1413	1676	919	2071

CHAPTER III

EXISTING FLOOD PREPAREDNESS ARRANGEMENTS

Introduction

The recent series of serious flood events in the metropolitan Phoenix area has resulted in the formulation and implementation of various preparedness actions. The purpose of this chapter is to describe in general terms the presently accepted (within the disaster management field) elements of preparedness plans and to catalogue the specific components that have recently evolved in the study area. The intent is to provide a basis from which enhancements may be formulated to strengthen the preparedness capability of the area.

Information developed to ascertain the nature of existing arrangements was derived primarily through extensive interviews with a wide range of local government officials involved in disaster management, private businesses, flood plain residents, and other related agencies and individuals. Other sources of information included newspaper and magazine clippings and post-flood documents prepared by several agencies.

Preparedness Plans - A General Description

Flood preparedness plans are generally comprised of components that provide for: recognition of flood threats; dissemination of warnings; emergency response actions; post-flood recovery and reoccupation of flooded areas; and continued plan management. Essential elements of each of these components are described in following paragraphs.

Flood Threat Recognition. The flood threat recognition component consists of means and procedures for identification of an impending flood and includes such activities as weather forecasing, precipitation and/or streamflow measurements, transmission of collected data, and processing and interpretation of collected data. The various activities must be specifically designed to provide accurate and timely warnings appropriate to the area to be protected. The procedures and means employed for flood threat recognition vary significantly in type and sophistication depending upon the characteristics of the stream system, nature of the area at risk and other factors. Principal features to the flood threat recognition system include: computerized systems featuring automatic remote or signaling capability between gages and a mini-computer

equipped with a rainfall-runoff model for prediction of flood information; various water level sensing devices which signal when stream levels reach some predetermined stage; and networks of observers who take direct readings of precipitation and river stages and forward the information to some central location for processing and interpretation.

Flood Warning Dissemination. Flood warning dissemination provides the critical link between recognition of an impending flood and execution of the emergency response actions. It consists of three main parts including: provisions for decision on whether or not a warning should be issued, and its intended audience; procedures for formulation of the warning message; and procedures and means for actual distribution of the message to affected parties by such means as radio, television, sirens, bullhorns, and door-to-door notification. The warning dessemination should provide for informing each individual who could be directly affected by the impending flood. The message should state the time available before flooding occurs, its expected severity, and describe appropriate response actions (evacuation routes, safe destinations, protective measures, etc.).

Emergency Response Actions. Planned activities that take place immediately prior to and during a flood emergency are designed to reduce the threat to life, and lessen the social and economic impact of the flood fall within this category.

Objectives of specific preparedness plans vary according to their completeness. Minimal plans are usually limited to measures for safety and general welfare of people; more comprehensive plans also address reduction of damage associated with flooding, while complete plans include provisions for the reduction of losses other than direct damage. Emergency response elements of preparedness plans normally deal with: search and rescue of endangered people; temporary evacuation of threatened areas; temporary relocation (removal or raising) of movable public and private property; flood fighting efforts; and management of important services and facilities such as those related to electric power, gas, water supply, sewage collection and disposal, fire suppression, law enforcement, and emergency medical service. Portions of the preparedness plan dealing with the above matters ordinarily consist of predetermined strategies for coping with one or more levels of flooding and the assignment of responsibility for their timely execution.

Post-Flood Recovery and Reoccupation. Post-flood recovery/reoccupation component of preparedness plans deals with steps and resources necessary to return the

community to normal status as rapidly as possible after a flood episode and mitigate secondary problems occurring in the post-flood period. Specific matters usually addressed in the post-flood recovery/reoccupation component include: the return to normal operation of important services and facilities, steps to prevent unsafe reoccupation of endangered structures, and identification and provision of assistance to the general public and local governments.

Continued Plan Management. Successful implementation of a community level flood preparedness plan during a flood episode requires a high degree of communication, cooperation and coordination between a broad range of public and private organizations and the general public. Interjurisdictional efforts between cities and counties are frequently required in implementation of successful preparedness plans.

Without periodic use, such arrangements are likely to become obsolete or unworkable. Continued plan management provides for actions needed to maintain the viability of the plan during the period between flood episodes. Continued plan management involves; updating of those portions of the plan subject to obsolescence such as telephone numbers, assignments of responsibility, etc.; provisions for maintenance and testing of equipment; and educational and informational activities including training of anticipated participants in plan execution, conduct of exercises and drills, conduct of public awareness programs, and education of the public with respect to actions to be taken during the floods.

Existing Preparedness Arrangements Overview

Status of Plans. A significant amount of flood preparedness planning has been done in the study area. In addition to the State's emergency plan, (State of Arizona no date), there are formal written plans for Maricopa County (Maricopa County 1980) and for most of the municipalities in the County. The procedure employed in the area of assigning responsibility to the Maricopa County Department of Civil Defense and Emergency Services (MCCD) for development of both county and municipal emergency plans has assured the compatibility and coordination of those plans. The MCCD has also prepared an extensive listing of resources which are available in the area.

The plans developed for the area deal mostly with warning, temporary evacuation, rescue, and other matters related to safety from the direct threat posed by floods.

Implementation of temporary flood mitigation measures, safety from secondary problems related to flooding, emergency management of important services and facilities, and post-flood recovery and reoccupation constitute a minor portion of the existing plans. Although present plans lack these elements, most people interviewed expressed satisfaction with the performance of emergency agencies during the February 1980 flood. Deaths due to past floods have been limited and the adequate warnings have enabled residents in the area to reduce damage through relocation or protection of property on an individual basis. There is no assurance, however, that existing arrangements for flood warning and preparedness will prove adequate in the event of an extraordinary flood.

Existing plans also contain some provisions concerning updating, practice, public awareness programs, or other activities to maintain the plan over the period between floods. The necessity of such activities is evidenced by interview comments that the effectiveness of emergency activities successively increased in each of the three major flood episodes occurring in 1978-1980. Plan maintenance, over a potentially long flood-free period at the high level of readiness existing after the February 1980 flood, requires undertaking specific activities for that purpose.

Central Arizona Hydro-Met Data Management Association (CAHDMA). Central Arizona Hydro-Met Data Management Association was organized early in 1979 as a forum for coordination of the use of member agencies resources for hydrometeorological data collection at existing and proposed sites. Membership of the organization includes local, state and federal agencies. The primary purpose of CAHDMA is to inventory existing data gathering equipment and arrangements and propose an enhanced data gathering system in order to improve flood threat recognition in the study area, improve forecasts of inflows to the major upstream reservoirs, and increase the accuracy of estimates of impending reservoir spills.

Flood Threat Recognition - Existing Arrangements

Provisions for flood threat recognition in the study area are quite sophisticated and well developed, particularly with respect to recognition of impending floods on the Salt River and its tributaries upstream of Phoenix, and prediction of the timing and magnitude of Salt River flows through the Phoenix metropolitan area. Recognition arrangements are less developed for areas along the Gila and Agua Fria Rivers.

Linkages for the exchange of information and data between various federal, state, and local agencies serving the area are strong, partially as a result of experiences in working together in the series of major floods occurring in 1978-1980. Operation of the system consists of the three general types of activities: collection of hydrometeorological data and information; assembly of collected data and information including, in some cases, its transfer to another organization; and interpretation of the data and information in terms of a flood prediction. Figure III-1 shows schematically the major linkages for collection and assembly of information for flood threat recognition in the study area.

Key Organizations. Three organizations have primary responsibility for performing flood forecasts for the study area. They include the River Forecast Center of the National Weather Service (NWS), Salt River Project, and the Arizona Flood Forecast Center. The Maricopa County Flood Control District also assists in forecasts for the Salt, Gila, and Agua Fria Rivers.

The River Forecast Center (RFC) at Salt Lake City, Utah is one of twelve such centers strategcially located throughout the United States. Its primary responsibility is the preparation of flood forecasts based on satellite information and on data forwarded by the Weather Service Forecast Offices (WSFO) within its service area. The RFC serves Arizona, almost all of Utah, and significant portions of Nevada, New Mexico, Colorado, and Wyoming. For the Salt, Gila and Agua Fria Rivers, flood forecasts are largely generated through use of computerized precipitation-runoff models (Owen 1980).

Salt River Project (SRP) is comprised of the Salt River Project Agricultural Improvement and Power District and the Salt River Valley Water User's Association. SRP's principal purposes are the conservation and delivery of water and the generation and service of electrical energy. The SRP has no legal authority to provide for flood control in its service area. Its participation in flood recognition activities is primarily to gain information for assisting in operations of its several reservoirs. Although the SRP has no flood control responsibilities, appropriate operation of its reservoirs can and has reduce flood peaks and thereby provide significant benefits (Owen 1980).

The Arizona Flood Forecast Center (AFFC) is a cooperative effort of the Phoenix Weather Service Forceast Office (WSFO) and the Arizona Water Commission. With respect to flood recognition within the study area, the Center's principal role is to collect and furnish data and information to the River Forecast Center for use in flood

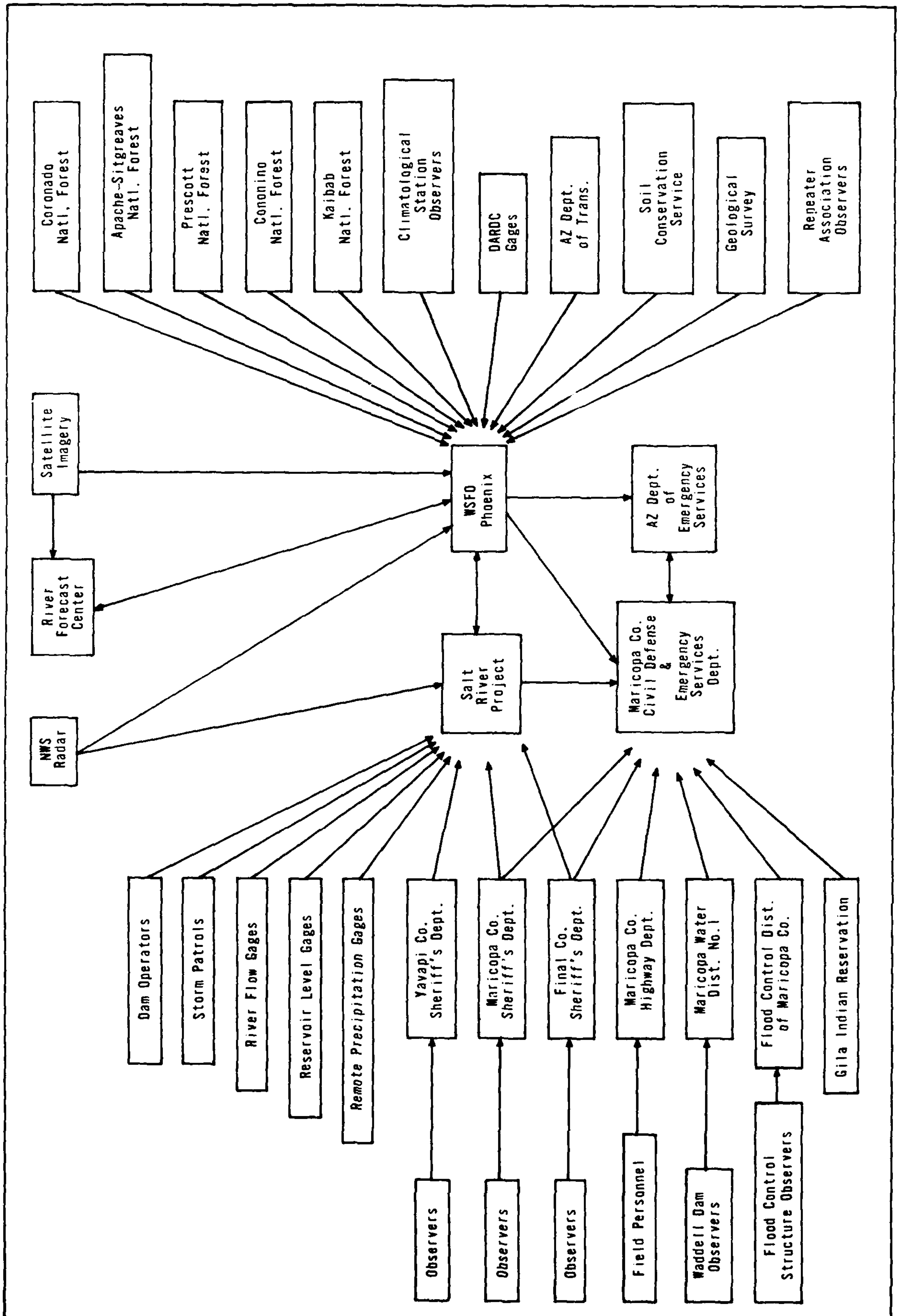


Figure III-1 INFORMATION SOURCES FOR FLOOD RECOGNITION

forecasting. Outside the study area, the AFFC will also prepare flood forecasts for streams not forecasted by the RFC. The geographic area of service is statewide. The Phoenix WSFO serves seven counties during the day and eleven at night, all of which are within Arizona (Owen 1980).

General Forecasting Operations. Information from a variety of organizations and individuals is furnished into the Arizona Flood Forecast Center (Figure III-1). A mini-computer located at the Center also receives data transmitted from automatic precipitation and river stage gages and interrogates telemark gages throughout the system at a frequency used on the intensity of past precipitation at gage sites. Data are relayed automatically to the RFC's computer system via NWS's data communication system. Using the data received and the NWS's Quantitative Precipitation Forecast (QPF) as input, the computer model generates a forecast for selected points along the study area streams, primarily upstream of the existing reservoirs. The models used for forecasting generate hydrographs on 6-hour time intervals which are calibrated to streamflow observations. Forecasts are upgraded as information becomes available.

Flood Warning Dissemination - Existing Arrangements

The warning dissemination aspects of the flood warning system in the study area are not as well developed as those for flood recognition. There is no comprehensive mass warning system for the area so distribution of warnings depends on use of a combination of radio, and television announcements, public address systems and various other techniques. The exact warning procedures used differ with location within the study area. There is a potential for shortage of emergency services personnel to assure that all parties which could be affected by a severe flood could be warned on a timely basis.

Flood warnings for the study area are originated by the Arizona Flood Forecasting Center and the Salt River Project. The Center's area of interest includes all of the study area while SRP's warnings are concerned almost exclusively with areas affected by discharges from its reservoirs on the Salt and Verde Rivers. Release of warnings for dissemination is informally coordinated between the two organizations and the Maricopa County Department of Civil Defense and Emergency Services (MCCD) through liaison, exchange of information and joint press conferences. Governmental organizations at the county level are contacted individually by the MCCD using telephone. Warning of rural and unincorporated areas is the responsibility of the Sheriff's Department, while

warnings in incorporated areas are disseminated by local police. The SRP notifies selected parties of its reservoir releases, Figure III-2 illustrates schematically the major responsibilities and lines of communication of warning dissemination as described by the people interviewed. The following paragraphs describe the warning procedures employed by the several agencies.

Emergency Response Actions

Formal plans for responding to flood emergencies in the study area are limited to the county's emergency plan (Maricopa County 1980) and those of affected cities. The County has also developed an emergency resource manual (Maricopa County 1979) listing sources of materials, equipment, and assistance available during disasters. Following paragraphs describe the county and city emergency plans with respect to the major objectives of evacuation, property protection, flood fighting and management of important services.

Temporary Evacuation. The County Emergency Plan provides for the Sheriff's office to be responsible for evacuation of unincorporated areas which are threatened by flooding. The plan also provides for the emergency staff at the County Emergency Operations Center to initiate and continue evacuation measures where appropriate. The plan contains an identification of flood prone areas for Holly Acres and Trilby Wash. Other locations within the unincorporated portion of the study area requiring evacuation due to floods are not identified. Community plans typically specify that police departments to be in charge of notifying people to evacuate, overseeing the evacuation, establishing evacuation routes and providing security for evacuated areas.

Temporary Flood Mitigation Measures. Formal County and City preparedness plans do not address individual or small grouped property losses due to floods. No provisions or guidance are provided for appropriate procedures and precautions to be undertaken to mitigate losses to structures and contents. However, some informal activities have been conducted by residents and businesses. The activities include limited scale implementation of perimeter barriers (earthern dikes, flashboard, and polyethylene) and removal of contents. Implementation of perimeter barriers have largely been unsuccessful in preventing inundation from flood waters but often have significantly reduced the amount of sediment deposition. The Salvation Army has assisted in the

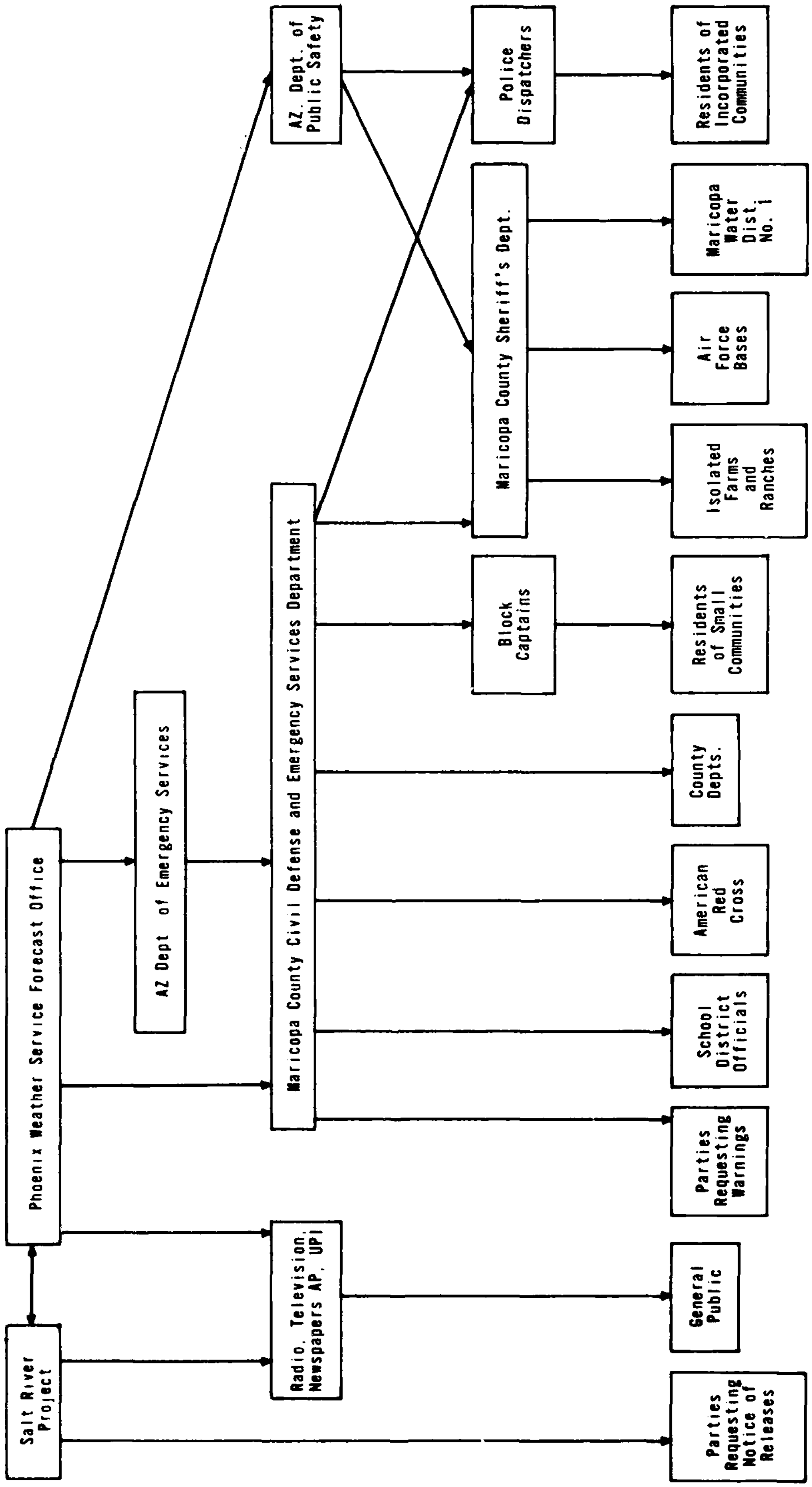


Figure III-2 EXISTING WARNING DISSEMINATION ARRANGEMENTS

evacuation of household goods from threatened areas and the police have occasionally provided security for areas where goods were stored.

Floodfighting. No official floodfight activities were conducted during past floods. However, the MCCD, County Flood Control District, and others have recently identified the most likely areas for effective flood fighting activities. The activities are intended to be implemented on a limited scale (two or three locations) during the next flood event, and if determined beneficial, on a larger scale for succeeding floods. Further assistance resource requirements, implementation methods, identification of other areas, etc., are needed.

Management of Important Facilities and Utilities. County and City emergency plans do not address management of telephone, gas, electric, water supply, and sewage disposal services during flood emergencies. Law enforcement, fire suppression, and emergency medical services are addressed. However, treatment of these important services is generally limited to describing their assignments in the overall disaster response. The plans do not identify the potential impacts of a flood on the facilities or the capability of the various organizations to perform.

Individual organizations have different approaches toward responding to floods. Some, like Arizona Public Service (electric), Mountain Bell, and agencies providing water and sewer service, only monitor their respective systems and respond to problems as they occur. Arizona Public Service (gas) throttles lines crossing the Salt River to prevent loss of gas in the event of damage. Most police and fire departments have informal plans for dispersing equipment to both protect them from flooding and facilitate service to all parts of their service area. All of the organizations follow the general practice of having staff report to work at locations on the side of the Salt River on which they reside regardless of their normal duty station. Again, however, this reallocation of emergency services staff is informal.

Post-Flood Recovery and Reoccupation - Existing Arrangements

The Maricopa County Peacetime Disaster Plan (Maricopa County 1980) defines recover/reoccupation elements of preparedness plans in an outline format. The plan classifies the functions as: assistance to the private sector; financial relief for governments; and preparation of post-flood reports and summaries.

During the emergency phase individuals and families may receive aid in the form of food, clothing, shelter, and health care as provided by the Red Cross, Salvation Army, or similar social organizations. Details and locations of distributions are to be publicized by the news media. During the post-flood recovery phase Disaster Assistance Centers may be established if the magnitude of the event is significant enough. The Centers are to be used to provide victims a central location to receive guidance and information, and to initiate their personal recovery actions (Maricopa County 1980).

Financial relief by Federal, State, and local governments and political subdivisions are available if specified conditions are met at each jurisdictional level: (1) the Chief Executive must declare a "local emergency" in the County; (2) the Governor must proclaim a state-of-emergency from the State; and (3) the President must proclaim a state-of-emergency in the County to receive Federal assistance. Assistance may be available for costs of emergency recovery work, costs of permanent restoration, and costs related to general emergency and recovery work (Maricopa County 1980).

Continued Plan Management - Existing Arrangements.

Several activities are periodically performed in an attempt by involved agencies to maintain the present state-of-preparedness that exists following recent floods. MCCD is required to update every two years the County peacetime disaster plan. Flood warning call lists for unincorporated areas are updated by MCCD every year or as information becomes available. Most of the involved agencies are required to perform disaster preparedness exercises every one or two years. These drills are generally performed by individual agencies, however, some are coordinated efforts among a few agencies. Public awareness broadcasts and publications by mass media sources are dispersed at the beginning of the flood season.

CHAPTER IV

FLOOD SCENARIO ASSESSMENTS

Purpose

Social scientists performing natural and man related disaster assessments over the past two decades have utilized scenarios as a forum to describe disaster related situations, consequences and social actions. Scenarios provide descriptive reinactments of past events or hypothesized situations in order to provide more explicit descriptions of possible catastrophic consequences and actions associated with potential events. The narratives enable sequential descriptions of integrated disaster actions and often bring forth a realism and understanding of the situations and consequences not possible in a structured technical format. It is within this framework that scenarios have applicability to flood preparedness planning investigations.

The purpose of this chapter is to present two scenarios of flood disasters that present hypothetical situations and conditions that might occur during floods in the Phoenix metropolitan area. Present preparedness planning arrangements are described and simulated to the extent possible. The first scenario presents situations that might arise during a flood of similar magnitude to the February 1980 event. The situations, conditions, and actions described are intended to be similar to those that occurred during the recent past floods in Phoenix. The second scenario describes a significantly greater event and presents several hypothetical situations either directly or indirectly related to the flood. While the probability of these situations occurring simultaneously within the duration of one event is extremely improbable, the potential does exist for one or more similar occurrences of like magnitudes. The intent is to present an awareness of the potential of these individual situations during a major flood event as a springboard from which enhancements to the existing arrangements might be formulated. Duplicate descriptions of the initial situations and conditions prior to spillages and subsequent floods on the Salt, Gila, and Agua Fria Rivers are minimized to a common scenario background setting.

Scenario Background and Setting

Personnel of National Weather Service (NWS) River Forecasting Center office in Salt Lake City closely monitor the 13,000 plus square mile Salt and Verde River

watersheds to the north and east of Phoenix. Isolated precipitation readings filtered into the center from GOES satellities, relayed telemark communitions, and manual observers. Information was also being received automatically from transmissions by the joint NWS - State of Arizona Forecasting Center located at Skyharbor International Airport in Phoenix. These data would be utilized in updating flood forecasts for the Phoenix metropolitan area by enabling predictions of inflow runoff hydrographs into the Salt River Project (SRP) reservoirs. Forecast results would be provided simultaneously to the Phoenix Flood Forecasting Center and the Salt River Project Office.

Radar monitoring of the present storm systems over the Salt and Verde River basins in the SRP flood operations room indicated locations of intense storm activities with moderate rainfall occurring over most of the remainder of the watersheds. The NWS five day meteorological forecasts were even more discouraging as the low pressure system off the southern California coast was located in a position which would allow storms off the West Coast of California to move unabated through Southern California and Central Arizona. Meteorological forecasts indicated that an average of three inches of rainfall could occur over the Salt River basin within the next two days.

SRP had been releasing 20,000 cfs through the Granite Reef Diversion Dam for the past five days in an attempt to reduce levels of the reservoirs on the Salt and Verde Rivers, which were 86 and 92 percent full, respectively. Chances of major spillages seemed not only likely but probable. A message was received within minutes from the Salt Lake City River Forecast Center predicting a major spillage of the reservoirs within the next 12-18 hours. Peak discharge was predicted to be 95,000 cfs without the additional forecasted rainfall. SRP personnel immediately issued the orders to begin maximum releases of 50,000 cfs in hopes of attenuating the flood peak through the Phoenix area. Continuously updated forecasts would be made based on revised data availability including potential precipitation amounts over the basin for the next few days. While the forecast models of the River Forecast Center enabled assessments of the precipitation on the snowpack, the SRP knew that these evaluations were somewhat subjective.

The Phoenix based Flood Forecast Center staff had worked through the night, as had those of the Salt Lake City office and SRP, monitoring the flood situation. Earlier in the week, flood warnings had been issued to radio and television stations and newspapers indicating that 20,000 cfs would be released from the reservoirs and that there was the

potential for greater flooding. This had created problems for the Phoenix area, closing numerous dip crossings and creating subsequent major traffic problems, especially during rush hour periods. Eight of the 31 crossings from Gilbert Road to Gillespie Dam remained opened. Only four, Mill Avenue, the I-10 Freeway, Central Avenue, and the Old Highway 80 crossing at Gillespie Dam would be opened during the morning rush hour if predictions of 95,000 cfs became true. Delays would be substantially longer than the hour presently experienced by the motorists.

Forecast information was immediately forwarded to the Maricopa County Department of Civil Defense and Emergency Services (MCCD) located on 52nd Street and a news release was drafted for the mass media.

Moderate Event Scenario

Note: This scenario represents an attempt to describe possible activities and occurrences associated with a moderate flood event (about a 50-year flood) in the Metropolitan Phoenix area. This event is approximately the magnitude of the recent 1980 flood. The descriptions are formulated from compositions of events and activities developed through the interview and analysis phases of the investigation. The scenario assumes other significant floods have occurred over the past several years.

By 1:00 p.m. the MCCD Emergency Operations Center was buzzing with activity after notification by the Salt River Project and Flood Forecasting Center of an imminent release of 50,000 cfs and forecasted spillage totalling 95,000 cfs for the Salt and Gila Rivers in the early morning of the following day. The possibility of additional intense rainfall over the Salt River watershed created even more anxiety. Fortunately, the storms had missed the upper watersheds of the Agua Fria River above Waddell Dam. Water District No. 1 was lowering the lake pool by releasing 10,000 cfs, essentially a nondamaging release.

The few hours of additional travel time required for the flood wave from Roosevelt and Bartlett Dams to reach the metropolitan area would prove valuable. Emergency response plans, reviewed and revised by the MCCD director and his staff over the past three days and the alerting of law enforcement agencies about expected heavy rain during the previous 12 hours, should provide sufficient lead time for the dissemination of the warning and corresponding emergency operations.

The director of the MCCD paused for a few seconds to look around the operations room. He felt fortunate that most of the people had previous experience conducting emergency operations during a major flood. The last flood, two years ago, was estimated to have a return interval of 30 years. Representatives from the SRP and Flood Forecasting Center were in constant communication with their offices to provide forecasting updates as they became available. The Sheriff, from the Emergency Operations Center, issued instructions via radio and telephone to his dispatcher for relay to his offices in the field. He had major responsibility for flood warning dissemination to the 19 unincorporated communities and rural areas of the county. Most of the larger of the 18 incorporated communities were also represented in the MCCD office. The noticable exception being the City of Phoenix which maintained communications with the emergency office via telephone. Other representatives present included those from the Red Cross, Maricopa County Health Department, Maricopa County Highway Department, SRP, Salvation Army, Maricopa County Flood Control District, the Water Districts, and several reporters.

At 4:00 p.m., revised forecasts received by the MCCD were for a peak of 110,000 cfs in the metropolitan Phoenix area to occur about 4:00 a.m. on the second of February. Forecasts of predicated peak flows based on analysis of one and three inches of precipitation uniformly over the Salt and Verde watersheds, were 180,000 cfs and 220,000 cfs, respectively. The peaks were estimated to occur on the third of February. These forecasts were immediately issued in the form of a news release to the reporters present.

Rain continued throughout the Phoenix area with over an inch recorded in the past 24 hours at Sky Harbor International Airport. Numerous streets were blocked due to local ponding. Law enforcement resources throughout the county were under staffed managing traffic, supervising the placement of barricades, and issuing warnings to businesses and residents along the rivers. Fire Department personnel assisted in warning issuances. Over 1,000 Sheriff's Posse comprised of volunteer senior citizens from the community of Sun City, were also assisting Law Enforcement Agencies in the placement of barricades. Traffic problems during the rush hour were major, but were only a prelude to those that would be encountered tomorrow when the water would be even higher. New bridges designed to pass up to 200,000 cfs were either still in the design phase or under construction. Those under construction would receive major damage.

Along the rivers, 2,000 residents were being temporarily evacuated from their homes, with stand-by contingency plans for several thousand more if the situation deteriorated. Many residents experienced similar evacuations in the past four years, and knew the proper procedures for shutting off gas and power at their homes and removal of personal contents. For most, assistance would be provided by neighbors and relatives. Private trucks and vans would be used to load and transport contents. The Salvation Army would also provide trucks and assistance for those in need. Most of the people would stay with neighbors, relatives, or in motels. Approximately ten percent would stay in the six mass care centers being established by the Red Cross.

An estimated 10-20 percent of the people would attempt to protect their homes with perimeter barriers (earthern dikes or polyethene plastic around their residences). Experience from previous floods indicated that the plastic would be effective for a small percent of the structures, and then only for flood depths less than a foot above the first floor. Polyethylene use in previous floods had, however, greatly minimized the amount of sediment deposited in the structures. Perimeter barriers constructed out of earth, sandbags, flashboards, etc., would prove more effective for depths of water up to 2-3 feet above the first floor. The resource requirements, people, heavy equipment and materials as well as the expense would greatly limit the implementation of these practices by individual homeowners. In Mesa and Tempe many mobilehome owners were preparing to move their homes. Several would be successful, while others on more permanent foundations, missing axles and wheels, or located in such a manner as to make removal impractical, would be flooded.

By 3:00 a.m., on the second of February updated forecasts predicted a peak of 175,000 cfs through the Phoenix area. Increased rainfall was predicted through 8:00 a.m. with more scattered storms occurring through the next two days. Intensity of the storms would likely dissipate after 8:00 a.m. Nevertheless, an event of 175,000 cfs would present significant problems. Forecasters were also predicting a peak flow of 30,000 cfs on the Agua-Fria by 4:00 p.m. that afternoon. Approximately 6,000 to 8,000 people would be evacuated throughout the metropolitan area, based on contingency plans from a flow of 200,000 cfs. Most of the evacuated would be from the Holly Acres, Avondale and Hound Dog Acres areas. Approximately 1,000 to 2,000 of those evacuated would be along the Salt River in the Mesa, Tempe, and South Phoenix areas.

At dawn, the flow was 90,000 cfs. The Sheriff's Office was preparing to evacuate 300 hardened criminals from the jail annex located at 3001 East Watkins Road to the

Durango minimum security facility located at Durango and 35th Avenues. This would be accomplished in about a two hour period under heavy armed guard. The Durango facility, already overcrowded, was designed to house 350 prisoners and would now temporarily hold 750 prisoners.

The Sheriff's Department was assisted by nearly 2,000 Sheriff's posse personnel and an additional 180 reserve police officers with training similar to regular police officers. These people were used in many forms of law enforcement activities ranging from supervision of placement of barriers to traffic control and warning dissemination. They allowed regular officers to perform more critical law enforcement responsibilities, such as, the moving of prisoners, rescue operations, and law enforcement surveillance in sensitive areas.

Power outages, although isolated, were occurring throughout the county. Many electric, gas, water, and telephone transmission lines crossing the Salt River had been broken with service disrupted until rerouted through auxiliary lines. Sewage disposal facilities along the Salt River would be flooded causing raw sewage to be discharged directly into the river. Since sanitary releases were diluted by the flood waters an immediate health hazard was averted. Specific sanitary facilities anticipated to be flooded were those servicing the Gila River Indian Reservation, Avondale, Phoenix, and Buckeye.

At 10:00 a.m. residents near 48th Street in south Phoenix were alarmed at the rising flood waters near their homes. Confusion in relaying warning messages by the Phoenix emergency office had apparently resulted in the Phoenix Police Department neglecting to issue the flood warning to people in the south Phoenix area. Although aware of the major flood magnitude by the mass media, the people relied primarily on information provided by local law enforcement personnel as to the extent of flooding and evacuation procedures. Several residents were consequently flooded before removal of their personal contents or attempts to protect their homes could take place. Another concern expressed by the south Phoenix residents, was the lack of sufficient medical services should a catastrophic accident occur. Fire protection and emergency medical services had been augmented the previous day by transferral of vehicles and paramedics from north Phoenix. Although a clinic was open, the nearest hospital to the south Phoenix area in the case of closure of the Central Avenue bridge were the Desert Samaritan Hospital in Mesa or Tempe Community Hospital in Tempe.

At 7:00 p.m. on the second of February, the peak of 182,000 cfs passed through the Phoenix area. Forecasts were for 120,000 cfs by noon of the third of February, 100,000 cfs at 6:00 p.m. and 85,000 cfs by midnight. Flows were predicted to be below 50,000 cfs by the fifth of February. Meteorological forecasts were extremely favorable with light scattered showers to occur throughout the remainder of the week. The worst was apparently over. Damage was expected to be $60 to 75 million, most of which would be the result of public facilities (bridges, roads, etc.) lost during the event. Flood elevations were lower than anticipated due to the degradation of the channel, attributed mostly to other recent events. This resulted in fewer homes being inundated than in previous events, although the peak discharge was higher. Emergency costs would amount to over $2 million.

Many evacuated residents whose homes were not flooded returned on the third of February. People whose homes were flooded would take up to two months to return. Clean-up efforts would be costly, with $55 million in disaster assistance provided by the President's designation of the metropolitan Phoenix area as a Federal disaster area. Two people lost their lives attempting to cross the Salt River on the first of February by circumventing an earthen barricade over a dip crossing.

This event, while significant and causing considerable disruption and damage, was not a particularly rare nor potentially cataostrophic event. Preparedness actions for the most part performed well and the various activities remained essentially within the bounds of management with local resources.

Severe Event Scenario

Note: The background scenario section of this chapter may be reread as a prelude to the following scenario. The following scenario presents events and actions associated with an extreme event that might occur perhaps once in a lifetime and assumes a substantial period has elapsed since the past flood. A significant turnover and deterioration in preparedness of public officials is postulated. This serves to emphasis the need for continued awareness and appropriation of resources to maintain a high level of preparedness and not a reflection of the present public officials. Although the scenario should not be considered an extension of the previous moderate event scenario, several situations described in the previous scenario that are pertinent to severe flood events were omitted to minimize duplication.

Notification by the SRP and Phoenix Flood Forecast Center to the director of MCCD informed him of an imminent release of 50,000 cfs from the upstream reservoirs and a predicted peak flow of 95,000 cfs for the Salt and Gila Rivers occurring the next morning. Although he had heard about the series of flood events 10 to 12 years ago, most conversations concerning water during his three years in Phoenix were about the severe drought of the past two years. Until two weeks ago he had never observed water in the main channel of the Salt River. Flood disaster conditions were new to him, having previous experience only in the development of contingency evacuation plans near nuclear facilities. One member of his staff remained from the floods experienced more than a decade ago. Since the initial recognition of the possibility of a winter flood last week, the director and his staff had reviewed documents of previous floods. Handwritten notes and general descriptions were found in two or three reporting documents. Essentially, documentation of appropriate emergency actions were nonexistent. Interviews with other local, county, and state agencies having a integral part in flood preparedness situations indicated they had similar problems, i.e., turnover in personnel, inadequate records, and no formal plans to conduct emergency operations during flood events. The exceptions were the joint State-NWS Flood Forecast Center at Skyharbor Airport and the SRP, which provided useful information of previous procedures for dissemination of flood warnings.

Late in the afternoon, county and local Public Works Departments were installing barricades under the specific direction of the law enforcement agencies. Law enforcement officers were also issuing local door-to-door warnings to the low-lying areas. Traffic problems were becoming major with the closure of many crossings. They were, however, placated somewhat by the 7 new bridges over the Salt River capable of passing 200,000 cfs. Continued rainfall and local ponding of streets were contributing a great deal to the adverse traffic situation.

Intense rainfall continued over Central Arizona throughout the early and late evening. Flash flood alerts and road closures, especially in the higher elevations, were being broadcasted almost continuously on television and radio stations. Rumors mixed with official reports were causing confusion among the citizens of the metropolitan area. Forecasts of predicted peak flows continued to be greater than those released only a few hours before. By midnight of the first, estimated flow at Central Avenue was 115,000 cfs with water levels rising rapidly. Revised forecasts, issued by NWS hydrologists at 6:00 a.m. on the second, were for peak flows of 250,000 cfs early the

next day. The forecasts were based on predicted additional rainfall over the upper watershed. The Agua Fria situation was also critical, with revised forecasts predicting a peak discharge of 80,000 cfs to occur between Waddell Dam and the confluence of the Gila River later in the evening.

Major concerns began to be expressed about the possibility of the metropolitan area being divided in the west and south and potentially from the rest of the state by the failure of the bridges and washed out transportation routes. Rumors, later proven groundless, were spreading through the area about the imminent failure of Stewart Mountain Dam and a nuclear disaster resulting from the loss of cooling water supply from the 91st Street sanitary facility to Palo Verde Nuclear Plant.

Evacuation of residents was proving difficult in many neighborhoods. Many were reluctant to leave their homes and possessions. Others, who had purchased homes after the floods a decade ago, and those whose homes were not threatened by previous events, were especially reluctant to leave. Many were confused at the contents of the warnings and of rumors that spread through the neighborhoods. Evacuees were overflowing many of the mass care center with other centers nearby relatively empty. Few residents knew where to go or what to do with personal property they managed to bring with them. Grocery and hardware store stocks were depeleted. Power, gas, and water lines, broken by the rampaging flood waters, had resulted in severed services to many throughout the metropolitan area.

By noon on the second of February, the discharge along the Salt River was estimated to be 195,000 cfs, and increased to 210,000 cfs by 5:00 p.m. Only the Central Avenue bridge remained opened, and it was scheduled for closure at 6:00 p.m. after the greatly reduced rush hour traffic. Other bridges were previously closed upon the continuous safety inspections or were destroyed. Traffic problems were fewer than previous days as many people heeded requests of public officials to remain at home. The rain, intense at times during the day, had lessened to a drizzle throughout the Salt River Valley.

Disaster struck at 5:30 p.m. as darkness set in throughout the area. Flood waters had reached the low steel of the Central Avenue bridge and debris began to pile up along the upstream side. From upstream a nearby empty petroleum tank had floated off its foundation, drifted slowly into the main channel, where some 500 yards above the bridge

it picked up speed and within seconds crashed full force into the center span. The crash knocked the span into the river immediately taking with it ten cars followed by four more before they could stop. Rescue attempts were hampered by traffic, flooded streets and the darkness of the evening. Only five of the estimated 23 people who plunged into the river survived. The bridge failure completely isolated the north and south metropolitan areas from vehicular traffic.

More disasters and problems were soon to follow. In the evening the storm increased again with local flooding prevalent along the washes and small streams, and water levels continuing to rise along the Salt, Gila and Agua Fria Rivers. Much of the area was in complete darkness, without power and gas. National Guard troops, located in the area, were assisting in law enforcement activities as ordered by the Governor. Other assistance was promised as soon as possible.

A three year old 12 story office building in downtown Phoenix caught fire in the early evening, fortunately at a time when most of the building was empty. Fire spread rapidly and unnoticed at first until shattering glass and bright flames lighted the night. The power outage had negated the operation of the automatic sprinkler and alarm systems to the nearest fire station. The result was the loss of precious minutes in fighting the fire and eventual total destruction of the building. No lives were lost and the fire was contained to a single building.

Late in the evening on the second of February, the peak of 76,000 cfs passed along the Agua Fria River. Devastation of the neighborhoods and communities located near the river had been great. Most affected were the Wigwam Trailer Park near Avondale, Avondale itself, Hound Dog Acres, El Mirage, and Rose Garden. Over 15,000 residents had been evacuated; many others were without services. Fifteen people were reported missing. Backwater from the high levels of the Gila River had resulted in greater water surface elevations than had been anticipated, causing many residents to leave their homes and possessions with little notice.

Flooding along the Salt and Gila Rivers was just as devastating, with the flood cresting at 285,000 cfs in the early morning of the third of February. Six people were reported missing on the Salt River Indian reservation with the prospects of more who resided in isolated portions of the reservation. Other areas greatly damaged included the Lehi neighborhood of Mesa, the North Tempe and Tempe Butte areas, Skyharbor

International Airport, south Phoenix in the vicinities of 48th Street and between 27th and 43rd Avenues, Holly Acres and Rainbow Valley. Over 12,000 people had been evacuated along the rivers. Looting and vandalism became a major problem in south Phoenix, stopped only by the stationing of National Guard troops in the area. Damage would run into the hundreds of million of dollars. The event would be the largest flood since the flood of 1891 which had an estimated peak discharge of 300,000 cfs.

Dawn of February the third brought with it clear skies for the first time in nearly a week. Residents of Rose Garden had been completely isolated. The sudden and unexpected return of power to the community resulted in an explosion heard for miles. A nearby gas line had ruptured in a flooded home, leaking unnoticeably until the spark from a light switch left on during the power outage detonated the gas causing the explosion. Two adults and a small child who had just returned to their personal belongings were immediately killed by the blast. Two other accompanying children were critically injured. Efforts by doctors flown in by helicopters to save the chilören were too late. Fire from the explosion spread rapidly through the two adjacent houses. Fire equipment from the nearest station was unable to reach the homes which were subsequently destroyed. Two other residents attempting to inspect the damage to their homes in Mesa, would have a similar fate three days later, when a lighted cigaret would detonate leaking gas from a ruptured line.

Rainbow Valley, the other major isolated area, would be supplied with vital and other important services by helicopters until crossings were constructed two weeks after the flood. Luke and Williams Air Force Bases would become centers for receiving and dispersing necessary supplies for the metropolitan area brought in from state and national relief organizations. Sky Harbor Airport would be closed for nearly four weeks after the flood until necessary repairs were made. The south runway would not be opened for commercial traffic for more than three months.

Numerous other flood related consequences would present problems to the area for weeks and months to come. Sanitary land fills, which contributed to the large amount of debris scattered throughout the flood plains, continuously smoldered and occasionally erupted in flames. The fire was the result of moisture expediting the decomposition of material and forming methane gas. Safe drinking water would have to be portaged into many neighborhoods for weeks. Effluent from nearly all of the areas sewage disposal facilities was released without treatment into the rivers until the plants received the

necessary major repairs to the treatment areas and equipment. Devastation by the flood was enormous with damage estimated to be nearly $600 million. Many businesses and commercial establishments would never reopen. Construction of dip crossings to enable transportation between the divided segments of the metropolitan area would take two weeks or more. The Mill Avenue Bridge, the only bridge left standing, would be nearly a month under repair before it would be opened for traffic.

The metropolitan Phoenix area has suffered a disaster of major proportions. The event was a rare one, expected but perhaps once in a lifetime. Preparedness activities took place and provided significant contributions to management of the crisis. It is also evident that the response would likely have been more effective had there been recent floods or had there been conscious efforts to maintain a state of readiness and alertness on the part of the local populace and its governing institutions. Opportunities for enhancements to the communications, emergency actions, and utility management are evident.

CHAPTER V

PLAN ENHANCEMENT MEASURES

Overview

Previous chapters have defined existing flood problems and presented results of both a flood hazard analysis and a damage evaluation of temporary measures, and correlated potential flood consequences and agency interactions through scenarios. This chapter presents and describes potential enhancements to present preparedness arrangements and procedures for the study area.

Preparedness plans and procedures consist largely of inter- and intra-organizational arrangements and commitments to performance in which the human element is an essential ingredient. As such, plans and procedures cannot be guaranteed to work in the same sense that a guarantee might be made for a piece of well tested equipment or a structure of concrete and steel. Preparedness plans are also vulnerable to decreasing effectiveness over time due to disuse, changes in circumstance such as community growth, and turnover of experienced participants. A primary consideration in the design of preparedness plans and procedures is therefore incorporation of provisions aimed at reliability and longevity. Among others, means of improving reliability and longevity include organizationally straightforward lines of communications, detailed description of actions to be taken, clear assignments of responsibility, incorporation of provisions for continuous plan maintenance, and formal implementation of the plan which embeds it in the community's administrative and institutional structure.

Evaluation of preparedness planning arrangements and procedures for the Phoenix metropolitan area indicate that their reliability, comprehensiveness and longevity could be enhanced by the following:

1. Modification of existing preparedness plans to formulate response actions on predicted water surface elevations instead of discharge.
2. Establishment of functional coordinations within the Emergency Operations Center along present responsibilities and authorities.

3. Streamlining and updating of arrangements for the collection of hydrometeorological data and information.

4. Modification and extension of arrangements for warning dissemination.

5. Increased development of detailed plans and procedures for:

   A. Evacuation of endangered areas;

   B. Flood fighting;

   D. Recovery/reoccupation actions in the immediate post-flood period; and

   E. Continuous plan maintenance.

Succeeding paragraphs describe each of these potential enhancements.

Response Based on Water Surface Elevations

The study area has available state-of-the-art forecasting of floodflows through the combined efforts of the NWS River Forecast Center, NWS-State Flood Forecasting Center, and SRP. However, relationships between flows and water surface levels for the streams in the area are unstable due to natural aggredation and degredation which takes place between and during flood episodes and due to gravel mining in river channels. Consequently, the nature and extent of response actions necessary for a particular predicted flow may vary from time to time. In order to avoid overreaction or underreaction to the actual threat, preparedness plans should be keyed to water surface elevations rather than to flows.

Accurate prediction of water surface elevations requires knowledge of the channel geometry and conveyance characteristics of river channels and areas of overbank flow. This information should be determined immediately after every significant flood and periodically thereafter (e.g., every 3-5 years) in order to assure availability of an updated information base. Revised water surface profiles and rating curves at several locations should be prepared based on the collected information. These profiles and rating curves would enable the NWS-State Flood Forecast Center to convert flow forecasts into predictions of water surface elevations at selected downstream points.

Stream level monitoring gages should also be placed at selected index locations. Six index locations would be sufficient for the Salt and an additional two on the Agua Fria River, three on the Salt River, and one on the Gila River downstream of its confluence

with the Salt River. These gages would enable checking and confirmation of predicted water surface elevations during a flood and collection of data valuable for future flood forecasting.

Maps of the area inundated at various water surface elevations should be prepared based on the profiles and used for planned flood response actions. An explicit analysis should be made for each selected water surface elevation to determine the needs for action with respect to evacuation, flood fighting, traffic control, management of important services and other emergency activities. Plans and assignments of responsibility should be organized so that all of the actions to be taken at each successively higher predicted water surface elevation are clearly apparent and described in specific terms.

Establishment of Functional Preparedness Coordinators at EOC

Numerous jurisdictions and agencies throughout the County have been invited to send representatives to the County's Emergency Operations Center during past flood episodes. No formal agreements exist to assure such participation and no formal organization exists within the EOC's operational procedures to allocate responsibilities to those representatives who attend. However, participation and responsibilities to those representatives are defined (in limited scope) in disaster plans of the County and local communities.

Proposed enhancements envision formal arrangements for six positions reporting directly to the director of the MCCD, staffed either by MCCD staff or, in some cases, by personnel of other agencies as shown in Figure V-1. The functions of the six positions would vary over the period of a flood. During the preflood period and during a flood, each position would have an established set of responsibilities for warning dissemination. During the flood, each position would also have responsibility for internal coordination (e.g., the law enforcement position would provide any necessary coordination between law enforcement agencies) and external coordination (e.g., coordination between law enforcement and health agencies). Responsibilities of each position would be documented. Each position would be staffed by a designated coordinator with alternates as needed to provide for 24 hour operations during flood

DIRECTOR
Maricopa County Civil Defense

LAW ENFORCEMENT COORDINATOR
(Sheriff's Department)

FUNCTIONS:

1. Incoming information from law enforcement agencies
2. Warning dissemination
3. Coordination of law enforcement activities
   - A. Warning
   - B. Rescue
   - C. Traffic control
   - D. Surveillance

PUBLIC ASSISTANCE COORDINATOR
(County Safety Department)

FUNCTIONS:

1. Incoming information
2. Warning dissemination
3. Coordination of volunteer activities
   - A. Shelter
   - B. Feeding
   - C. Floodfighting
   - D. Post-flood recovery

PUBLIC WORKS COORDINATOR

FUNCTIONS:

1. Incoming information
2. Warning dissemination
3. Coordination of public works and utilities
   - A. Monitoring
   - B. Curtailment of service
   - C. Restoration of service

FIRE SERVICES COORDINATOR

FUNCTIONS:

1. Incoming information
2. Warning dissemination
3. Coordination of fire department activities
   - A. Warning (back-up)
   - B. Emergency medical

MEDICAL SERVICES COORDINATOR
(County Health Department)

FUNCTIONS:

1. Incoming information
2. Warning dissemination
3. Coordination of medical services
   - A. Air evacuation
   - B. Distribution of supplies
   - C. Distribution of injured
4. Post-flood health measures

EMERGENCY OPERATIONS COORDINATOR
(Flood Control District)

FUNCTIONS:

1. Warning dissemination
2. Coordination with federal agencies
3. Coordination with state agencies
4. Floodfighting
5. Property damage reduction measures

MEDIA SPOKESMAN
(MCCD Staff)

FUNCTIONS:

1. Press briefing
2. Rumor control

Figure V-1 ENHANCED EMERGENCY OPERATIONS CENTER ORGANIZATION

periods. Each coordinator would supervise whatever staff was necessary to assist them in carrying out the assigned responsibilities of their position.

The proposed set of coordinators would assure that the director of the MCCD is adequately supported by specialized staff. It would also have the advantage that experience gained in flood operations would be more likely to be preserved than under existing arrangements in which different people come and go from flood to flood. As a side benefit, the total number of people involved in the EOC operation would be reduced, thereby lessening the possibility of congestion and confusion, contributing to more orderly and efficient operations, and freeing personnel resources for other purposes.

Update Arrangements for Data Collection

Hydrometeorological data and information useful for flood prediction in the study area is available from a variety of sources. The lines of communication by which such information has reached those responsible for preparing the flood prediction in the past are shown in Figure III-1. As shown there, the MCCD has played a key role in the collection of local data and its forwarding to the Phoenix WSFO.

Creation of the NWS-State Forecast Center enables revision of the lines of communication for assembly of flood related data. One potential revision is shown in Figure V-2. The revised arrangements provide for data to go more directly to the intended user, thereby minimizing the potential for introduction of errors and contributing to more timely issuance of flood predictions. Elimination of the need for MCCD to serve as a data collection point also frees that agency's resources for meeting its warning dissemination and other emergency responsibilities.

Modify Arrangements for Warning Dissemination

General arrangements used in the past for dissemination of flood warnings are shown in Figure III-2. As noted previously, these arrangements do not comply in all respects with Maricopa County's formal emergency plan. They also include cases in which unnecessarily repetitious warnings are given to some organizations and cases in which greater duplication of warnings would be desirable to assure reliability.

Proposed revisions of arrangements for warning dissemination are shown in Figure V-3. Revised arrangements would consolidate warning responsibilities at the MCCD,

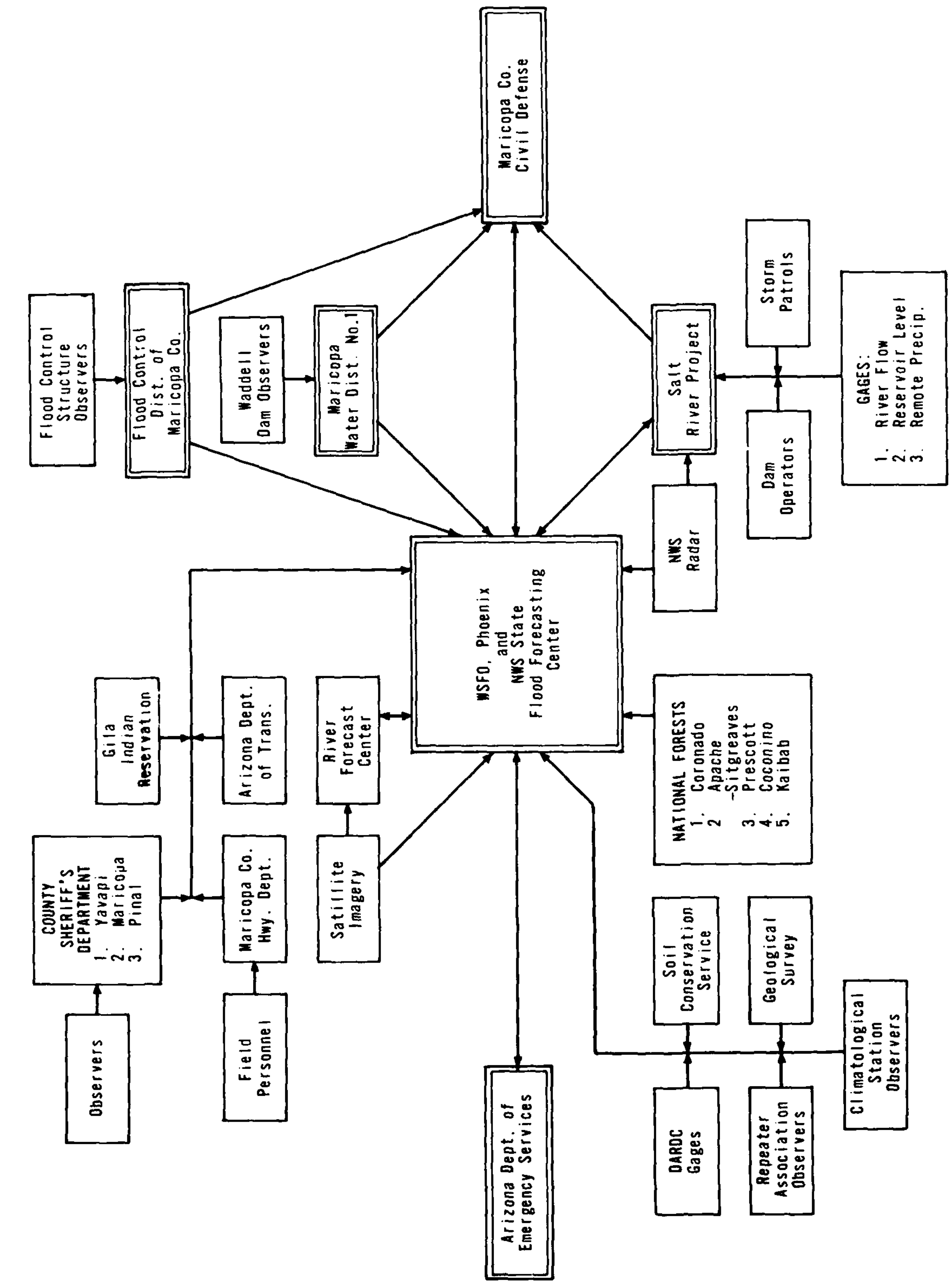
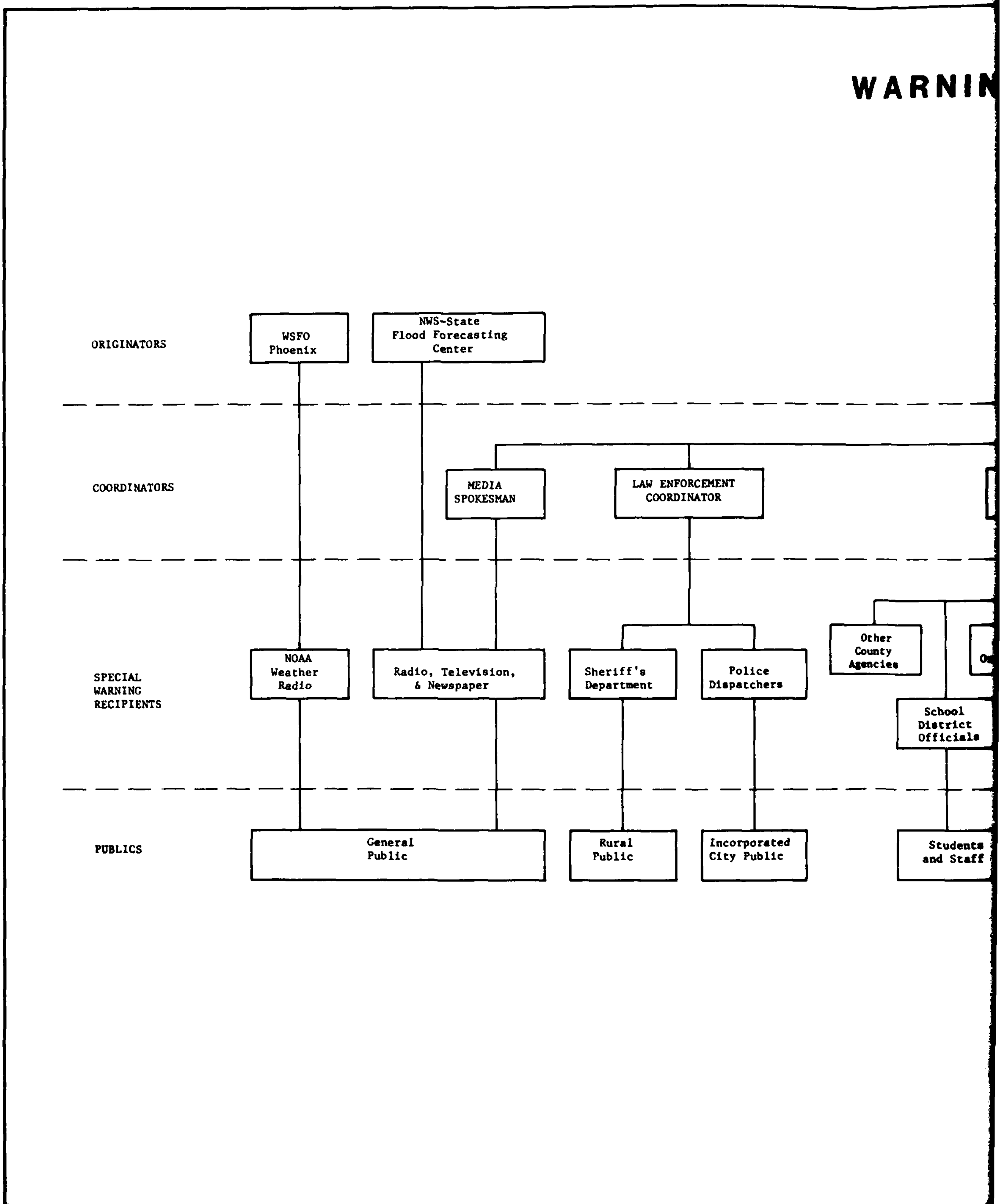


Figure V-2 ENHANCED DATA COLLECTION ARRANGEMENTS


WARNIN
ORIGINATORS
WSFO Phoenix
NWS-State Flood Forecasting Center
COORDINATORS
MEDIA SPOKESMAN
LAW ENFORCEMENT COORDINATOR
SPECIAL WARNING RECIPIENTS
NOAA Weather Radio
Radio, Television, & Newspaper
Sheriff's Department
Police Dispatchers
Other County Agencies
School District Officials
PUBLICS
General Public
Rural Public
Incorporated City Public
Students and Staff

ARNING DISSEMINATION PROCESS

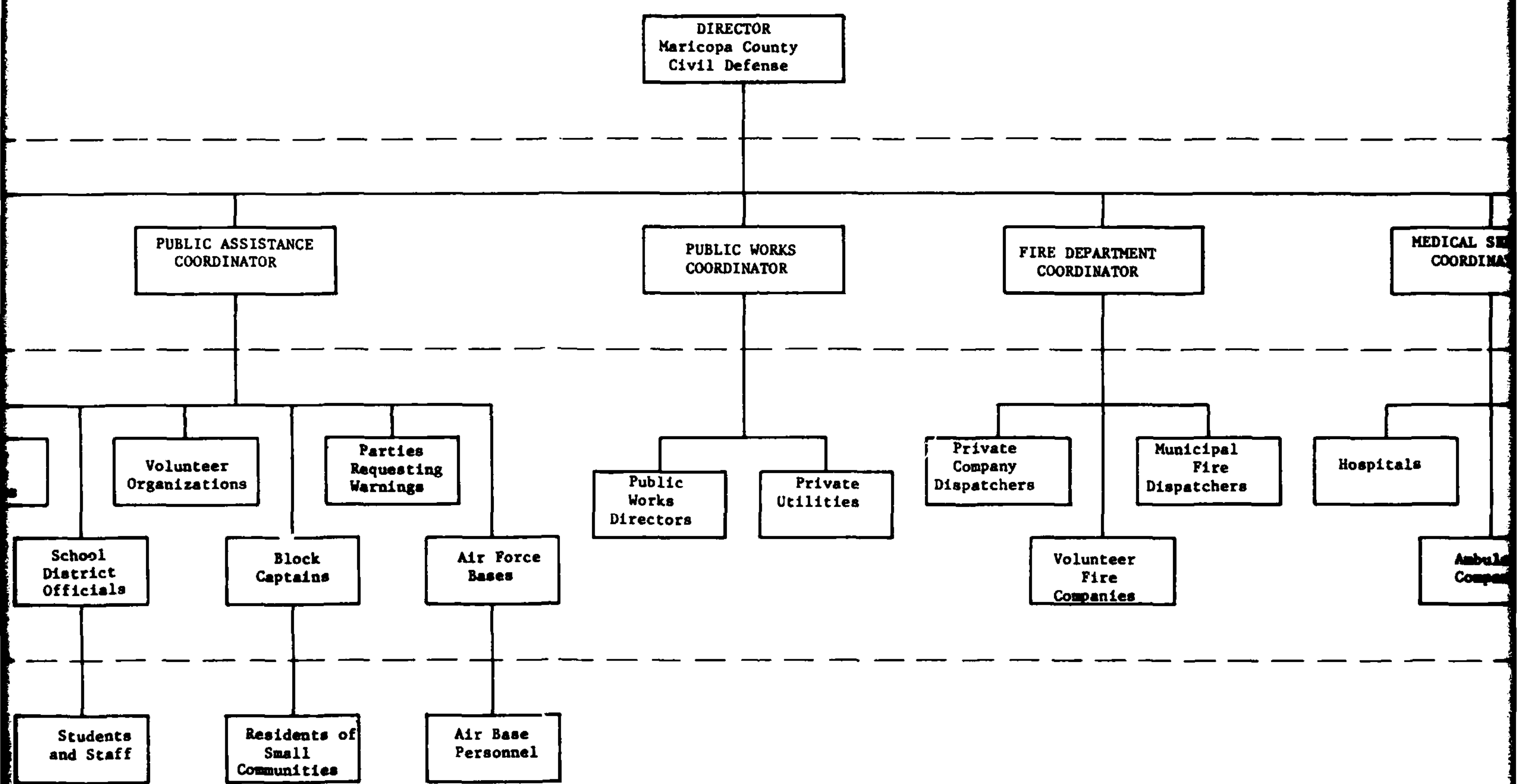


Figure V-3.

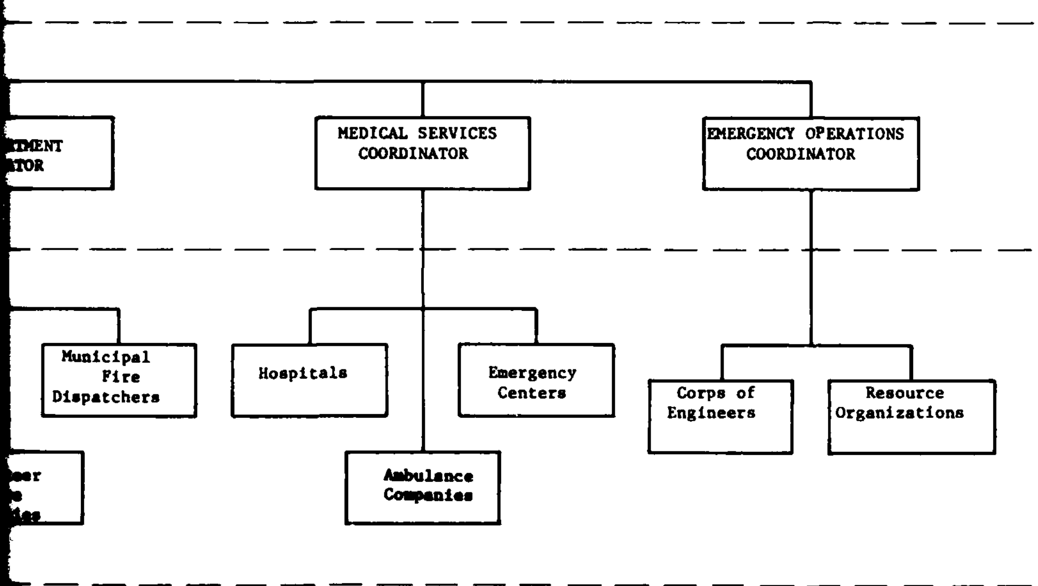


Figure V-3. ENHANCED ARRANGEMENTS FOR WARNING DISSEMINATION

excepting statements over NOAA Weather Radio issued by the NWS Weather Service Forecast Office and statements to the media by the NWS-State Flood Forecast Office. However, the possibility of conflicting statements being issued by the several parties would be minimized since information releases by the NWS and the NWS-State Flood Forecast Center would consist largely of predictions of flows and water surface elevations while information issued by the MCCD would generally be guidance on the appropriate response to such predictions. Releases of the several parties would also still be coordinated through joint press briefings as has been done in the past. A position of media spokeman is shown for the MCCD to free the director from routine inquires and permit full attention to overall direction of EOC activities.

Development of Formal Plans for Evacuation

Significant sized portions of the study area are subject to flooding and therefore require evacuation during floods in the interest of safety. Other portions of the study area are subject to total or near total isolation by flooding so far as land routes are concerned. Isolation from law enforcement, fire protection, medical treatment and other emergency services poses hazards in addition to floods. People in isolated areas are also at risk in the event of subsequent higher floods due to lack of an escape route. Some areas subject to a significant degree of isolation also require timely evacuation in the interest of safety, depending on the resources located in the area, degree of risk and other factors.

Present plans have selected evacuation levels based on relations of predicted discharge values to respective flood inundation boundaries delineated on aerial photographs. Modification to present procedures should be made to base evacuation boundaries on predicted water surface elevations instead of discharge. The reason for this is the continuous change in the riverbed and due to the alluvial nature of the river and the intense gravel mining operations in the channel. More specific plans are needed to identify evacuation routes, shelters, etc.

Much of the information necessary to develop a detailed evacuation plan is readily available. Considerable information on the number and type of structures to be evacuated is presented in Chapter II. The principal remaining needs are for:

Identification of areas expected to require evacuation at each of several water surface elevations;

Detailed arrangements for feeding and sheltering evacuees;

Development and stockpiling of brochures describing evacuation plan arrangements and actions to be taken by property owners prior to evacuation;

Arrangement of safe storage areas for property removed from evacuated areas; and

Development of implementing arrangements including those required to enable mandatory evacuation of threatened areas.

Development of Formal Plans for Direct Damage Reduction

Organized efforts to reduce damage by implementing temporary flood mitigation measures either to individual structures or on a larger scale have not been undertaken on any widespread basis during post-floods. However, the MCCD, Maricopa County Flood Control District and other agencies have recently identified potential areas for future fight efforts. Analyses of Chapter II and interviews (Hydrologic Engineering Center 1980) support these and comprehensive efforts. The findings indicate the combination of topography, available warning time, nature and extent of development in the study area, and other factors exist for preventing significant damage through relatively small efforts. The flood mitigation efforts comprise of those implemented either to individual structures or on a larger scale of block or neighborhood.

The study indicated that implementation of effective perimeter barriers and raising or removal of contents presents a means of significantly reducing damage to residential, commercial and industrial structures on an individual structure basis. Locations identified (Hydrologic Engineering Center 1980) as having potential for larger scale floodfight efforts are: Lehi area in Mesa; 48th Avenue between 27th and 43rd Avenues; Pierce Road in south Phoenix; Indian School Road at the Agua Fria River; the I-17 crossing of Skunk Creek; and waste water treatment plants. Public and quasi-public structures and facilities which warrant priority consideration for application of such measures are law enforcement facilities, fire stations, and electrical substations and switchyards.

The principal matters to be accomplished in the development of plans and procedures for flood fighting are: they must begin with specific identification of areas where organized public flood fighting efforts would be productive at various water surface elevations. Analysis of public flood fighting opportunities should be performed

with respect to available warning time, techniques to be employed, requirements for equipment and personnel, relative priority, impact on traffic, and other factors. Sources of equipment and personnel needed for public flood fighting efforts needs identification. Development of implementing arrangements for public flood fighting efforts, including provisons for stockpiling or obtaining necessary equipment and obtaining needed personnel is required. The types and quantities of materials to be stockpiled for distribution to private property owners for use in individual flood fighting efforts need to be identified and arrangements formulated for safe storage of public and private property which is temporarily relocated during flood periods.

Development of Plan for Management of Important Services

Floods disrupt the provision of vital services by damaging facilities and equipment. Flooding of normal routes of access also makes delivery of some services either difficult or impracticable for some areas. In some cases, the continuation of utility services in inundated areas also poses risks.

All major problems pertinent to management of important services could be treated through development and implementation of a series of emergency plans and procedures. Principal matters to be accomplished are:

1. Development of a formal inter-jurisdictional plan for dispersal of fire and police equipment and personnel at each of several water surface elevations, based on past experience and on analysis of needs in the case of floods greater than those experienced in the past.

2. Development of specific plans for management of utilities crossing the Salt, Agua Fria, and Gila Rivers including provisions for detailed monitoring of performance during floods, revised operations to reduce losses in the event of damage (e.g., minimizing flow in gaslines), prompt cut-off of damaged services, rerouting of services (e.g., use of alternate sources of water supply), and use of substitution services (e.g., temporary installation of microwave links for telephone communications).

3. Development of plans for curtailment of gas and electric service in areas as flooding occurs.

4. Development and execution of implementation arrangements including any modifications or supplementations to facilities which are necessary to enable opeation of the plan.

Develop Plan for Recovery/Reoccupation

Prompt action in the immediate post-flood period can reduce secondary losses stemming from flooding, improve safety, and speed return to normal conditions. Among others, the types of post-flood actions likely to be required are financial assistance, emergency clean up, inspections of structural building safety; vector control and chlorination of contaminated wells. Existing plans, as previously described in Chapter III, provides some assistance to individuals, financial relief for governments and preparations of post-flood reports and summaries. Development of more specific aspects of post-flood recovery and reoccupation are needed.

Land fills present a potential serious problem during floods. If not properly regulated placement of fills may significantly increase flood heights, scatter debris downstream, and present a direct risk to life. Some present flood plain fills contain toxic chemicals which have been dispersed into the river during recent floods. Also, rapid decomposition of fill material occurs when the fills are saturated, resulting in a sufficient production of Methane gas to pose a risk of fire and explosion. Several *sanitary fill fire* were reported during past floods (Hydrologic Engineering Center 1980). Restriction of access to such areas in the post-flood period is needed so long as sanitary land fills exists on the flood plain. The need also exists in the post-flood period for inspection of damaged structures, restoration of public services and provision of information to property owners on dealing with flood damage.

Development of Enhancements for Continuous Plan Management

Continuous plan management procedures are essential for maintaining the reliability and effectiveness of preparedness plans. This is especially true in the study area because long periods of time are likely to elapse between floods. The passage of time, coupled with the typically dry stream channels and poorly defined flood plains, erodes public awareness of the flood hazard. The effectiveness of preparedness plans is reduced over time by turnover of personnel, changes in the area at risk and changes in the flood hazard.

Present flood preparedness plans for the study area have elements for continued plan management as described in Chapter III. Proposed enhancements are designed to maintain the present level of agency and public awareness of the flood threat in the future. The following are identified as possible enhancements:

1. Explicit procedures and documentation on updating agency personnel telephone numbers, addresses, and responsibilities. This is presently being performed to a large extent, but any additional steps to better assure periodic updating of plan procedures and responsibilities overtime should be performed.

2. Location of equipment and materials for flood fighting efforts, both large scale and for private individuals. Also include means of making public aware as to best locations.

3. Preprinted brochures describing appropriate actions to be taken by the general public during flood situations. The brochures would be distributed each flood season or during the early flood threat recognition phase. The brochures should include explicit descriptions, materials and illustrations for:
   - A. Means of obtaining flood information.
   - B. Procedures for temporary evacuation: possible items to take, and leave; content adjustments (raising or removal); shut off water, gas and electricity; and security precautions.
   - C. Flood fighting procedures for individual structures: placement of earth fill; sand bags; flashboard and polyethylene.
   - D. Recovery and reoccupation procedures: general assistance; financial assistance; safety considerations prior to reentry.
4. Other means of distributing information to the public might include preprinted newspaper inserts, seminars and workshops for specific areas.
5. Periodic coordinated drills (say 3-4 years) among involved agencies.
6. Periodic evaluation and modification of the plan to adapt it to community growth and other long-term changes that take place.
7. Negotiation and renewal of contracts, inter-jurisdictional agreements, memorandum of understanding and other implementation arrangements as necessary.

CHAPTER VI
EVALUATION OF PROPOSED PLAN ENHANCEMENTS

Purpose and Overview

The purpose of this chapter is to assess the value of the proposed preparedness planning enhancements (as determined in the investigative process and presented in Chapter VI) and discuss the relationship of preparedness plan elements to other flood mitigation alternatives. Preparedness plans are unique among flood loss reduction measures due to the potential for implementation decisions of measures on an event basis. This enables flexibility in preparing for a broad range of mitigation procedures not possible in permanent measures. However, the event oriented temporary nature of the measures, variability of actions, the relationship of the effectiveness of the actions to the nature of the event, community status and a myriad of other factors result in considerable uncertainty in the reliability of the measures. The measures function differently (event basis) than those of permanent alternatives which are designed to operate in a specific manner for a range of hydrologic occurrences. Consequently, evaluations of the proposed enhancements to present plans center around two distinct aspects. First is the determination of the value of proposed enhancement increments over present plans and arrangements, in the traditional project life evaluation sense, and second is the actual feasibility (decision process) of implementing those measures for a specific flood event. Understanding of the two different aspects of feasibility assessments is important in differentiating the functions of preparedness plans from other flood mitigation measures.

The feasibility assessment of traditional flood control plans is approached through consideration of benefits and costs and evaluation of social/institutional impacts. Evaluation of the costs and benefits of preparedness plans in general, and specifically in this case, i.e., proposed enhancement increments to existing plans and arrangements, are particularly difficult since implementation involves a range of flood events.

An evaluation vehicle that seems to offer considerable value for the nature of the proposed enhancements reported herein is that of a scenario forum. The thrust would be to describe modified arrangements and measures activiated during flood situations in such a way that the contribution of each element is evident in comparison with the

without condition. A scenario based assessment has therefore been prepared and is presented as a major element of the plan assessments.

A cost-benefit focused assessment has also been attempted and is presented. The major goal was to bracket the likely limits of the investment required to implement the recommendation and to identify the nature and source of these costs.

The relationship of the individual elements of the preparedness plan to other flood mitigation alternatives presently under investigation by others is also presented.

Scenario Assessments of Plan Enhancements

Purpose of Scenario. Evaluation of the proposed preparedness plan enhancements is performed using a scenario of significant flood event and assessing the differences in actions between this event under present conditions. The scenario forum is intended to enable the reader to more clearly understand agency interactions, sequential emergency actions and event consequences. The discussion between present conditions scenarios (Chapter III) and those with the proposals in place are hoped to enable direct assessments of the value of the proposed enhancements.

It is suggested that the reader reread the Severe Event Scenarios. The following paragraphs are the major deviations from the previous scenario with the enhancements proposed herein in place and operating.

Severe Flood Scenario-Enhancements in Service. The director of the Maricopa County Civil Defense paused as he read the updated flood forecasts just issued by the NWS--State of Arizona Flood Forecast Center. The forecasts predicted a peak discharge of 85,000 cfs on the Agua Fria River and 250,000 cfs on the Salt-Gila Rivers to occur at midnight and near dawn the next morning, respectively. The forecasts were predicated on the weather front presently located in central Arizona continuing to move through the region by late in the afternoon. Present discharge at the Central Avenue gage was estimated to be 93,000 cfs. This discharge represented the highest flow in a decade and the first flood since the director took office nearly three years ago.

Although somewhat anxious and inexperienced with regard to flood events, the director felt a quiet assurance and competence that he and others involved in the

emergency actions in the following hours would manage the situation as best as possible given the trying conditions. Damage and social disruptions would be major, although certainly less than had no preparedness plans existed. The plans, originally documented in detail about 8 years previously, had continuously been updated to reflect changes in personnel, organizational responsibilities and flood plain conditions. The formal preparedness plan provided information and insights for emergency action decision making purposes. The actions were formulated by progressively implemented bases upon predicted water surface elevations at four streamgage (index) locations along the Salt and Gila Rivers and two on Agua Fria River.

In addition to continuous updating of formal preparedness plans, other actions had been taken at the start of the flood season, and in the previous two weeks when long-range meteorological forecasts indicated continued heightened potential for flooding. A coordinated flood emergency drill among the responsible agencies had been conducted in late fall prior to the flood season. This consorted exercise was conducted on three-year intervals and provided insights and experiences normally obtainable only during actual flood events. Materials, stockpiled in late fall for flood fighting needs, had been made available for immediate distribution in emergency situations. Public awareness programs via mass media had routinely been performed each fall and increased during the past month as the potential for floods increased. Resource availability of heavy equipment, trucks, moving vans, storage locations, etc., had been reinventoried and their present utility determined during the past two weeks. Prepublished pamphlets describing detailed procedures for temporary evacuation, utility shutoffs, adjustment (removal or raising) of personal contents, implementing protective measures and reoccupation guidelines had been widely distributed to the potentially inflicted public and businesses during the past three days. Similar information was being published in local newspapers and broadcast on special programs via radio and television daily.

The director of MCCD called a meeting with the assigned coordinators of various emergency activities to discuss the recent flood forecast, predicted impacts, and appropriate emergency actions. The coordinators had been actively stationed at the emergency operations center for the past three days, since the recognition of a potential for spillage had been made. The sheriff, responsible for law enforcement emergency actions in the county, had already issued revised warning messages to the dispatcher in both the sheriff's offices (unincorporated areas) and local police departments

(incorporated areas). The coordinator of emergency operations with responsibilities for implementing temporary flood mitigation measures had been especially busy dispersing equipment and materials to local field operation offices. Additional supplies of such items as sandbags, polyethylene, small pumps, and generators, were being delivered from national sources via the Corps of Engineers. Other coordinators, responsible for medical, fire, and public utilities had also been active in taking appropriate actions and receiving feedback on situations in the field.

Late into the evening temporary evacuation of people was continuing along the three rivers. Most residents and commercial and industrial establishments had worked feverishly to raise or remove contents. Many were installing temporary perimeter barriers of earth or sandbags in conjunction with polyethylene. Over 12,000 residents were evacuated with approximately one-half staying in the 30 mass-care centers established throughout the metropolitan area. Storage locations established for personal property were under surveillance by the National Guard although most residents stored their property with friends or relatives. Utility service to the flooded area was shut off by public works and gas and power companies as neighborhoods were evacuated.

Dawn of the following day brought with it recognition of the devastation and disruption of the flood plain areas in the metropolitan area. Every bridge along the Salt and Gila Rivers linking the north and south areas was destroyed or structurally unsafe for vehicular traffic as were the structures along the Agua Fria. The metropolitan area would remain divided for two weeks after the flood waters receeded until temporary crossings were constructed. Indirect damages to business due to employees being unable to get to work would be major. Emergency vehicles would also be unable to cross the rivers.

Damage, which was extensive, was estimated to be $485 million. Five people were missing and assumed drowned. Although damage were high and disruption great, preparedness plan emergency efforts had reduced damage and minimized potential accidents that might have resulted in catostrophic losses of life and property. Predetermined evacuation procedures and public awareness programs had greatly minimized confusion. An estimated forty percent of the people, commercial, industrial, and public works agencies removed a significant portion of their movable property. An estimated 80 percent of the people raised their personal contents. Some form of temporary perimeter barriers were implemented to about thirty percent of the

structures with greater success than originally conceived. In all damage to residential, commercial and industrial structures and contents were reduced by an estimated $17 million.

Recovery and reoccupation of the flooded area required several months of intensive effort. Traffic was able to cross the quickly installed dip crossings in three weeks. Individual site inspections of homes and businesses prior to return of utility services caused some friction among public works and utility employees and local residents; however, no explosions or other accidents were reported. Cleanup operations were time consuming and costly. Two to four months would pass before most residents reoccupied their dwellings and businesses returned to normal operation.

Epilogue. The preparedness actions had served their purposes well. Emergency services had been provided in a planned, coordinated and managed way. The threat of life had been kept to the minimum possible under the circumstances. Confusion and the attendant uncertainty were minimized. Temporary flood mitigation measures resulted in a modest but real reduction in flood damage. A major disaster had struck and significant social disruption and damage occurred even with the implementation of the preparedness measures. The measures did, however, enable the emergency operations to be conducted in a managed way; and to the extent possible, minimized the potential for loss of life, reduced flood damage to residential, commercial, industrial and public properties and minimized the general confusion and disruption in the evacuated area.

The development and continuous updating of formal preparedness plans enabled the inexperienced (with respect to floods) director of the emergency operations center to conduct the emergency operations in an effective manner. Having coordinators, and having them stationed at the emergency operations center resulted in the reduction in the number of people required at the center and made for more effective communications with field operations. Significant improvements were highlighted in public awareness of appropriate response and implementation of temporary damage reduction measures. Coordinated and predetermined actions relating to management of important services enabled utilities to be operated in a more effective and safe manner. Post-flood recovery and reoccupation was still lengthly but perhaps less disruptive than under present conditions.

Cost-Benefit Analysis

Scope. The objective of cost-benefit economic analysis is to identify, array, and estimate the cost of actions needed to bring an alternative into operational service and maintain its viability; and to identify, array and value the output (benefit) of the alternative in commensurate units so that the justification of the investment may be determined. Previous discussions have indicated that the various elements of preparedness plans are varied and difficult to array, in the usual style, and that the output services (benefits) are even more difficult and diffuse, except for perhaps the temporary flood mitigation measures. The attempt here will be to meet the spirit of the cost-benefit framework, with particular attention to the identifing, arraying and estimating the cost of the various elements.

Preparedness Plan Cost Items. The elements of the preparedness plan enhancements have been mentioned previously in Chapter V. Costs required to implement the plan enhancements consist of: (1) first costs of formally investigating and adopting the plan element themselves and to acquire, develop, and prepare in a state of readiness, those items needed for the general plan implementation; (2) annual periodic costs of maintaining plan elements in a state-of-readiness; and (3) events costs associated with implementing specific actions during flood events. Table VI-1 itemizes and summarizes general cost items associated with the proposed preparedness plan.

Preparedness Plan Cost Estimates and Discussion

It is immediately recognized that there are difficulties in distinguishing between cost items that may already fall within the perview of an existing agencies operations, and those that are not presently accounted for. In general, the approach has been to assign most administrative costs to existing on-going programs and specifically identifiable products as bonafide cost increments. The intent also has been to attempt to separate out those items that could be specifically assigned to the enhancements proposed in this report.

Development of formal plans, e.g., written documents of procedural actions and administrative arrangements must of necessity be prepared by the local agencies involved. It is envisioned that the "plan" might consist of a set of instructions for the director/staff of the emergency operations center and for the several coordinators.

TABLE VI-1

PREPAREDNESS PLAN COST ITEMS

First Cost

Development of formal plans
Outfitting/equipping administrative facilities
Purchase and installation of equipment and hardware
Development/printing brochures, instructions etc.
Stockpiling equipment and materials

Annual Periodic Cost

Updating formal plans
Updating /printing brochures, instructions etc.
Operations drills
Supplement/replace stockpiled materials
Periodic river section surveys

Event Cost

Personnel overtime and emergency hiring
Equipment purchase and rental
Transport/storage of personal property
Materials/supplies consumed
Mass care operations
(And severalfold more general items)

Each agency/group with a specific role to play in the emergency operations could well have their own procedures documented for their own use. The responsibility for the development of the plan at the emergency operations center level would be the existing MCCD director. Overall coordination, plan documentation and arrangements preparation is estimated to cost a one time increment, over and above the existing responsibilities of MCCD, of $100,000. The preparation of action plans on the part of the responsible participating agencies are assumed to be part of the functional role of these agencies and have no direct cost.

The purchase and installation of equipment and hardware is specifically related to the recommendation of adopting index stations along the main streams for stage forecasts. The initial costs of installing hardware for continuous monitoring of flood elevations at selected index locations on the Salt, Gila and Agua Fria Rivers is $60,000 to $80,000. This cost would include the installation of six stream gages with automatic data transmission capabilities and a receiver and printer located at the NWS-State of Arizona Flood Forecast Center.

The development and printing of public awareness brochures, pamphlets, preprinted newspaper inserts, etc., are estimated to be $75,000 to $125,000. Distribution of these information materials would be made early in the flood season on a general scale, or immediately prior to a predicted event or threatening situation on a mass scale. The information would include general information for temporary evacuation, temporary floodproofing procedures, content adjustments, and post-flood recovery/reoccupation considerations. More specific information on technical guidance for significant self help type temporary measures may be warranted and would cost an additional increment. The specific scope and number of public information needs would be determined as a part of the formal plan preparation. The need for stockpiling of equipment and materials should be investigated in some detail. Emergency equipment for preparedness agency use includes such items as portable pumps and generators, shovels, sandbags, etc. An inventory of the resources available for such emergency use is needed to define new purchase needs. Since only limited flood fight activities have been attempted in the past, the availability of such items as shovels, sandbags, polyethylene plastic, etc., has not been determined. It is conceivable that the formation of a central storage area for regional distribution (say southern Arizona) might be reasonable and economical. A one time purchase of equipment and materials for public agency use, as an upper estimate might be $75,000 to $100,000.

Stockpiling or arranging by some contingency contract for materials and small equipment for use by private citizens in a self help mode is a specific endeavor that warrants serious study. Materials on the order of $200 per structure would allow preventing upwards of 1 foot of water from entering certain types of structures. As an outside estimate a contingency contract for on-short-call delivery of materials for 1,500 homes might cost 25% of full cost or $75,000. The expected use rate is a function of flooding frequency. The expected annual number of structures that would be flooded can be computed from data in Figure II-7 and is 65. Increasing this number by 50% to allow for conservative estimates of material consumption for temporary flood damage mitigation results in 100 structures per year.

The annual costs associated with the proposed enhancements include general maintenance of equipment and programs described earlier, extra costs for periodic drills and the cost of material consumed for temporary flood mitigation measures. Maintenance of the automatic stream gage system, periodic updating of cross section information, and subsequent rating functions is estimated to be $10,000 to $20,000.

Annual rent and contingency lease for materials requisition and storage of flood fight equipment is estimated at $5,000 to $10,000. Public awareness programs and printing/distribution of brochures, drills, etc., are estimated to cost $15,000 to $25,000 per year. The annual cost of materials consumed for temporary flood damage flood mitigation is $200 per structure or $20,000. The cost information discussed above is summarized in Table VI-2.

TABLE VI-2

PREPAREDNESS PLAN COST SUMMARY

First Cost

Item	Cost Range ($1,000)		
Formal Plan	$75	-	$100
Office/Administrative Outfilling	0	-	0
Equipment/Hardware (Stream Gage)	60	-	80
Information/Brochures	75	-	125
Equipment/Materials (Agency Use)	75	-	100
Equipment/Materials (Temporary Flood Mitigation)	75	-	75
Totals	$360	-	$480
Amortized (50 Yr.@ 7-3/4%)	28	-	38

Annual Cost

Item	Cost Range ($1,000)		
Equipment/Hardware (Stream Gage)	$10	-	$20
Storage/Rent	5	-	10
Public Information/Brochures, Drills	15	-	25
Flood Mitigation Materials	20	-	20
Totals	$50	-	$75
Total Annual Cost Range	$78	-	$113

Costs in Perspective. Costs incurred during the occurrence of a significant but not major flood event are expected to be about the same as without the proposed plan enhancements. It is expected that the more effective management and communications

as proposed would in fact result in not only increased effectiveness but would likely result in lower overall costs. Costs incurred during the occurrence of a major flood in which significant attempts are made to aide in private/individual temporary flood mitigation actions could be significant. On an annual basis these costs may, as an upper limit, increase the annual cost by 10%, given the rare occurrence of major floods.

The investment cost range of $360,000 to $480,000 is judged to be a conservative estimate. It may well be that several of the items included can be absorbed by the normal activities of the existing agencies. This is even more true for the annual recurring cost items total ranging from $78,000 to $113,000. For discussion purposes, the total investment cost can be adopted as $450,000 and total annual cost, including amortized investment and levelized event costs, as $110,000.

Benefits. The benefits of flood emergency preparedness have been described previously as primarily reducing the threat to life and to a lesser extent mitigating the negative impacts of flood disasters on society in terms of reduced social disruption, business losses and damage to private and public building and facilities. Table VI-3 summarizes the general categories of benefits from the proposed preparedness plan.

TABLE VI-3

GENERAL BENEFIT CATEGORIES - PREPAREDNESS PLANS

Category	Contributing Action
Reduced threat to life	Barricading, evacuations, rescues, public awareness
Reduced social disruption	Traffic management, emergency services, public awareness
Reduced health hazards	Evacuation, public information, emergency services
Reduced disruption services	Utility shutoffs, emergency supplies, inspection, public information
Reduced Clean up costs	Flood fighting, self help mitigation, efficient resource use
Reduction in inundation damage	Flood fighting, temporary measures, technical assistance

The contribution to increased effectiveness and efficiency of emergency actions with the proposals were presented in a scenario forum earlier in this chapter. While significant monetary benefits are in all likelihood generated by these contributions, an estimate of their numerical value has been found to be impossible. Debates as to valuing the saving of lives and reducing threats to lives and property have occurred for many years and are continuing. The growing activities in the U.S. in the general area of emergency preparedness provides general evidence that society places sufficient value on these endeavors to support use of scarce financial and manpower resources to increase their responsiveness and utility.

Some measures of the flood damage reduction value, mostly due to private citizen actions from implementation of temporary flood mitigation measures, can be inferred from data presented in Table II-8. The reader is cautioned again that the values presented are preliminary and at best are but indicators of the true damage that might occur. For discussion purposes, let's assume that on the average, 30% of the flooded properties would attempt to implement perimeter barriers, that most would make some attempt to adjust contents to a less vulnerable position through either partial removal or elevation. Further, let's assume that the perimeter barrier attempts would be 50% successful and that content adjustment actions would be 40% removal of half the contents and 80% of the remaining contents raised. These are the scenario values previously presented. Table VI-4 summarizes the results of these actions.

Based on damage reduction from temporary measures alone (no credit for flood fighting, effectiveness of emergency services, etc.) a crude estimate of the annual benefit would be a minimum of about $390,000.

Cost-Benefit Summary. Cost items have been identified and initial and annual cost ranges estimated for the major items. The total investment cost range is estimated at $360,000 to $480,000 with a reasonable value of $450,000 adopted for analysis purposes. The total annual cost including amortized investment, recurring annual costs, and event costs levelized is estimated at $110,000. It is judged that these costs are on the conservative side and that it is likely that several of the items would fall within the normal activities of existing agencies. The benefits are primarily contributed to reduction in the threat to life and increased effectiveness of emergency services and recovery. A monetary estimate of these benefits is not presented. The benefit from implementation of temporary flood damage reduction measures, made possible by the

TABLE VI-4

DAMAGE REDUCTION ESTIMATE

Measure	Annual Damage ($1,000) 1/	Annual Damage Reduced ($1,000)	Adjusted* Reduction ($1,000)
Existing	$2,454	$0	$0
1 Foot Barrier	2,142	312	$47
40% Content Removal	1,676	778	156
85% Content Raise	2,071	383	184
		Total	$387

1/ Data from Table II-8, also note cautions.

* Perimeter barrier - 30% attempt, 50% effective
Contents removal - 40% removed 50% of contents
Contents raise - 80% raised 85% of contents 3 feet

collective capabilities of the preparedness plan *enhancements* is crudely estimated at a lower bound of $390,000. Based on these estimates, the preparedness plan enhancements proposed are clearly economically justified.

Relationship of Preparedness Plan to Other Alternatives

The purpose of this section is to present the relationship between the proposed preparedness plan actions and future development, structural flood mitigation measures, and nonstructural flood mitigation measures. The descriptions are for future "without" conditions and for future conditions assuming implementation of the alternative flood mitigation measures presently under investigation by others. They may be classified as measures designed to specifically modify the flood event and measures designed to reduce the damage susceptibility of the threatened area. Measures under investigation that modify the flood event include: several reservoirs (either new or altered) incorporating flood control storage; and levees and channel capacity *improvements*. Measures under consideration which modify to some extent the damage susceptibility include: permanent floodproofing and structure relocation; flood insurance (transfer of

flood costs and flood plain zoning); flood plain regulation (future development); gravel mining guidelines; and construction of new bridges.

Impacts of Future Development. Preparedness plans for future conditions without implementation of permanent flood mitigation measures would perform basically as presented. Flood insurance and other regulations are expected to prohibit development in designated floodway areas and below the existing 100-year flood elevations in flood-fringe areas. Development in the flood plains above the 100-year elevatons, if significant, will require updating of formal plans of emergency operations for these areas. Encroachments on the conveyance system by natural vegetation, development fills, waste fills or other means would increase the frequency of areas inundated if the encroachments are significant. This would have no effect on the formal preparedness plans, if developed as proposed, based on water surface elevations instead of discharge, but would have an effect on the frequency of their implementation.

Nine new bridges designed to pass 200,000 cfs (present conditions) are scheduled for completion by early 1983 (Los Angeles District 1980b). These bridges are in addition to the existing structures at Central Avenue and Mill Avenue which have somewhat similar design capacities. The result will be significant improvement in traffic conditions for flood events with magnitudes between the 10-year and 100-year events. The value to preparedness actions will be increased mobility of emergency vehicles (fire, medical, law enforcement) and a reduction in some of the traffic control needs, thereby, enabling law enforcement officials to perform other tasks for the range of flood events.

Other readily identifiable potential consequences of future conditions, such as flood plain development, are likely to have minimal effects on preparedness plans as presently conceived. Future plans should function essentially as present plans with proposed enhancements.

Alternatives Modifying Flood Events. The feasibility of implementing physical flood control structures for reducing flood losses in the study area is presently under study by others. Physical works under investigation include: new and modified existing reservoirs on the Salt, Verde, and Agua Fria Rivers, improvements to channel carrying capacities, and levees. Channel improvements being addressed are clearing of natural vegetation along the Salt and Gila Rivers from 91st Avenue to Gillespie Dam and channelization of the Salt River from Country Club Road to 35th Avenue. The potential levee system being investigated is from County Club Road to 35th Avenue (Bureau of

Reclamation, 1979). There is a growing recognition among water resource agencies and the public of the need for viable preparedness plans to enhance permanent flood control measures. Preparedness plans may be essential for: design exceedance situations of dams and channels and for catastrophic structural or other failures of dams and levees, as well as, provide limited potential for enhancement of the effectiveness of these structures during occurrences of less than design exceedance events. Flood control works are normally designed to provide high levels of protection in urban settings. Developmental encroachments to the design levels is common, with often severe consequences when the levels are exceeded. Although reservoirs and channel works will continue to attenuate flood levels over natural conditions for flood design exceedance situations, the opposite is true with levees where design failure may result in sudden major losses. Well developed and formulated preparedness plans are needed for emergency actions associated with the above described events.

Preparedness contingency plans for emergency operations associated with potential structural failure of existing or proposed upstream reservoirs above the metropolitan area are also needed and in fact mandated for projects constructed by the Corps of Engineers (Hydrologic Engineering Center 1980b). The probability of such occurrence is rare, however, the possibility does exist and local concern has surfaced as evidenced by media reporting of possible failure of Stewart Mountain Dam during the February 1980 flood. Formal plans should be developed for these contingencies.

Alternatives Modifying Damage Susceptibility. Flood mitigation measures that modify the damage susceptibility of threatened areas include: permanent floodproofing (perimeter barriers and raising); permanent relocations; flood plain regulatory policies; and flood insurance. Feasibility studies of implementing these measures for the study area are presently under investigation by others. The measures, which are designed to reduce inundation losses to individual structures, are typically justified by only frequently flooded structures and are implemented on a block and neighborhood basis. It is unlikely that these measures could be justifiably implemented on a massive scale. Many flood related problems remain after implementation of these measures necessitating the need for preparedness planning activities. The following paragraphs describe preparedness planning aspects required to augment these measures.

Floodproofing measures are the installation of permanent earthen barriers, seals, or permanently raising of structure. Direct floodproofing of a structure is usually limited

to less than two feet due to physical constraints of the structure. Effectiveness of floodproofing usually diminishes with time and with prolonged periods between flood events because of decline in public awareness and material availability for closure of openings. The damage reduction and susceptability to flood events exceeding the design would be the same as described in Chapter V for temporary floodproofing measures. All other aspects of preparedness plans would be necessary, including: sufficient warning time, temporary evacuation, adjustment of contents and management of important and vital services. Raising of structures effects the damage susceptibility to the structure and contents. The measure has the reliability benefit over installation of perimeter barrier. All other aspects of preparedness plans previously described are applicable.

Permanent relocation directly negates the need of preparedness planning actions for areas where implemented by removing people, structures, contents, and services from flood threat areas. Implementation of these measures are normally for only small segments of flood threatened areas and thus would have little effect on needed comprehensive preparedness plans for the metropolitan area.

All aspects of preparedness plans are applicable with structures having flood insurance. Regulatory aspects concerning future development above existing 100-year flood levels will have little effect on preparedness plans. The long-term Federal Insurance Administration's authorized flood plain regulatory objective of purchase of property subjected to repetitive damage or damage beyond repair (Federal Flood Insurance Act 1968) may eventually significantly reduce the damage potential and necessary emergency actions in the 100-year flood plain. Another aspect of the flood insurance program is that the implementation of temporary protective measures to structures and adjustments to contents may presently result in uncertain insurance payments to the subscriber. If the implementation costs of these actions are borne by the subscriber, as is the usual case, the incentive for taking preventive actions may be significantly reduced.

Flood plain regulatory policies typically limit new development to above 100-year flood elevations. These policies will have little effect on presently conceived needs for flood preparedness plans.

Summary

Proposed preparedness planning enhancements are economically feasible. They are expected to have a positive impact on the social well being of the area. Preparedness plans will contribute to mitigation of flood damage and social disruption in the interim until other flood loss reduction measures are implemented and will continue to provide value by augmenting the effectiveness of those measures after installation.

Implementation decisions of selected aspects of emergency actions during flood event situations are dependent upon several factors: nature of the flood (magnitude, duration, etc.); warning time; community status; awareness of appropriate actions by officials and the public; resource availability, etc. Comprehensive preparedness plans are designed to assist decision makers by providing information on appropriate actions through predetermined data and contingency plans for numerous potential situations. These plans (and associated actions) are formulated based on knowledge of: flood elevation- inundation consequences; institutional arrangements, authorities and responsibilities; flood hazard and damage potential data; and other factors. During flood situations, decisions are predicated on current flood situations, preparedness plans and experiences of those involved. The more complete the preparedness plan, the more likely the implemented actions will follow those recommended, the less complete, the less likely.

Materials developed throughout this investigation and presented herein are, to a large extent, information that may be utilized in the decision process involved in implementing emergency response actions to flood crises situations. Graphical displays indicating numbers and types of structures inundated by reach may be used in determining evacuation criteria for predicted flood levels. The graphics illustrating damage reduction for temporary floodproofing and content adjustments may be utilized to indicate the value of implementing such actions on a large scale. (The results indicate significant damage reductions for large scale events.) The attached supplement provides information on water surface elevations at index locations versus flood inundated consequences. Each of these items are provided to assist in developing enhanced emergency operation plans and for input into the decision making process of implementing emergency actions.

The final decision on implementation of emergency actions must be made during the flood crises situations. Preparedness plans provide the organizational arrangements and predetermined action plans to assist in the process. The feasibility of such actions may be obvious or not so clear. The better the information and knowledge, the better the chance of good decisions being made by rational decision makers.

APPENDIX A

REFERENCES

APPENDIX A

REFERENCES

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APPENDIX B

FLOOD DAMAGE EVALUATION

PROCEDURES

AD-A117 813 HYDROLOGIC ENGINEERING CENTER DAVIS CA F/G 13/2

FLOOD PREPAREDNESS PLANNING: METROPOLITAN PHOENIX AREA,(U)

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APPENDIX B

FLOOD DAMAGE EVALUATION PROCEDURES

General Approach

The objective of the flood damage analysis was to develop damage information and perform systematic assessments of temporary flood mitigation measures. The analysis focused on preventive measures associated with residential, commercial, and industrial structures, which were identified as having the greatest likelihood of implementing flood mitigation actions. Also developed were information sets depicting the number of structures at or below specific elevations which may be used to estimate the potential number of structures inundated by specific events, number of people evacuated, etc.

Damage evaluation procedures made use of automated retrieval and processing of geographic information sets (spatial data) from a grid cell data bank. The procedures developed elevation-damage relationships by damage category and reaches. Land use definition, topography, damage reach delineations, and reference flood elevations were obtained for the Salt and Gila River flood plains of the study area from cartographic sources. These data were encoded into a grid cell format, maintaining proper legending and using procedures previously developed (Hydrologic Engineering Center 1976, 1978). Three grid cell data banks were constructed by the Los Angeles District for the investigation because of an identified need for different topographic and land use specificity throughout the study area. Two data banks, Mesa and 35th Avenue to Buckeye, were developed using grid cell sizes of 4.60 acres while the data bank from Mesa to 35th Avenue (including Tempe and Phoenix) was based on a 1.15 acre grid cell size.

Damage functions were developed automatically by the DAMCAL (Hydrologic Engineering Center 1979) computer program by constructing unique elevation-damage relationships for each grid cell based on ground elevation, land use classification and specified damage potential associated with land use. Table B-1 is a tabulation of the land use categories used in this study. Functions for each cell were aggregated to designated damage reach index locations adjusting for slope in profiles by use of reference flood elevations. The elevation-damage functions were the results of

DAMCAL output by damage category and damage index location. DAMCAL results were used in conjunction with hydrologic data (flood frequency and rating functions) to obtain single event damage values (direct from DAMCAL) or expected annual damages using the Expected Annual Damage Computation Program (Hydrologic Engineering Center 1977). Adjustments to the elevation-damage relationships of each damage category associated with implementing temporary flood mitigation measures is made in DAMCAL based on user specifications. The evaluation procedure is repeated for modified conditions. Figure B-1, schematically depicts the process.

Damage Function Development Criteria. Assessment of existing damage potential was limited to residential, commercial, and industrial structures. Damage reaches were delineated, based on desired information displays for jurisdictional community boundaries and consistent sets of water surface profiles for a range of discharges. Sixteen damage reaches were delineated from Mesa to Buckeye.

The December 1978 flood was designated as the reference flood based on inspection of several historic and hypothetical flood profiles through the study area. Reference flood elevation assignments to each grid cell enabled adjustments for water surface slopes during the aggregation process to index locations.

Composite damage functions for each damage category were developed, based on user input specifications to the DAMCAL program. Initial composite damage functions for each damage category were provided by the Los Angeles District (1980). These were later adjusted so that results approximated percent of damage, total damage and number of structures inundated by the March and December 1978 floods.

Composite damage functions (land use associated) for each grid cell were matched with the topographic elevation of the cell to generate elevation-damage potential relationships for the cell. These functions were then aggregated to index locations to yield aggregated elevation-damage functions by damage category for each damage reach.

Flood Damage Evaluations. Flood damage evaluations of present conditions and conditions assuming implementation of temporary flood loss reduction measures were conducted using spatial data processing and analysis procedures. Evaluation of

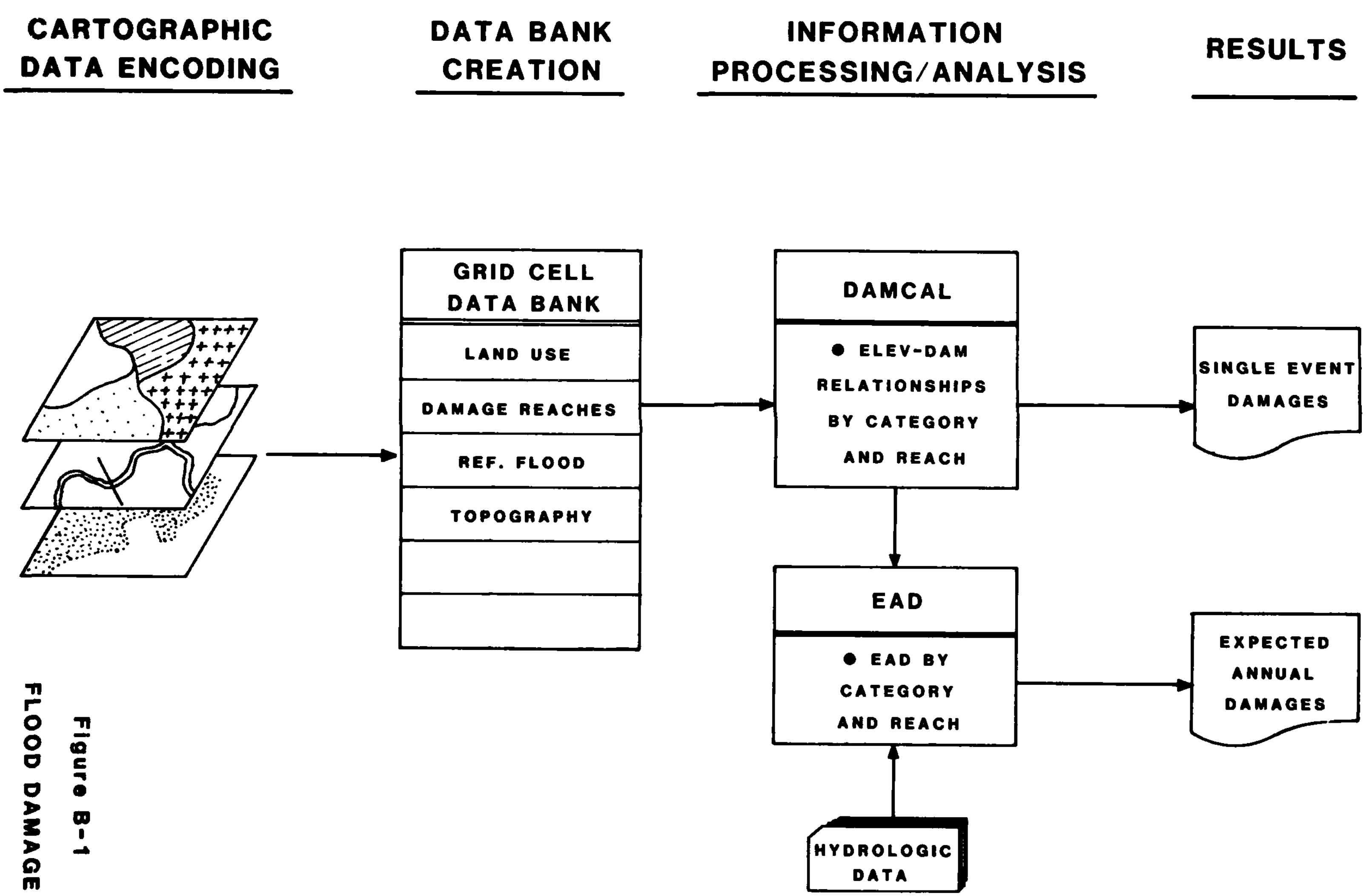

Figure B-1

FLOOD DAMAGE

EVALUATION PROCEDURES

TABLE B-1

DEFINITION OF LAND USE CLASSIFICATIONS

1. LOW DENSITY RESIDENTIAL Single Family: Average 1 unit per acre. Areal Breakdown: 5% structures; 10% pavement; 25% lawns, 60% barren or vegetation. Proportion developed = 25%

2. MEDIUM DENSITY RESIDENTIAL Single Family: Average 1 unit per 1/4 acre. Areal Breakdown: 15% structure; 15% pavement, 40% lawns; 30% vegetation or barren. Proportion developed = 85%

3. MOBILE HOMES Single Family: Average 1 unit per 1/5 acre. Areal Breakdown: 15% structure; 25% pavement, 30% lawns, 30% vegetation or barren. Proportion developed = 95%

4. HIGH DENSITY RESIDENTIAL Multi-Family: Apartments, townhouses, etc.: Average 1 unit per 1/5 acre. Areal Breakdown: 25% structure; 20% pavement, 25% lawns; 30% vegetation or barren. Proportion developed = 85%

5. COMMERCIAL Shopping centers and "strip" commercial areas. Average 1 structure per 1/2 acre. Areal Breakdown: Structures 30%; pavement 55%; lawns 5%; vegetation 10%. Proportion developed = 60%

6. INDUSTRIAL Industrial centers and parks, light and heavy industry. Average 1 plant per 1-1/2 acres. Areal Breakdown: 20% pavement; 50% structures; 30% open space. Proportion developed = 40%

7. INSTITUTIONS AND AIRPORTS Public institutions and facilities, airport facilities, runways, etc.

8. PARKS Community parks, golf courses, cemeteries, etc.

9. AGRICULTURE Cultivated land, row crops, small grain, etc.

10. TRANSPORTATION ROUTES AND BRIDGES Highways, roads, streets and bridges.

11. POWER SERVICE Power facilities and transmission lines.

12. UNDEVELOPED FLOOD PLAIN AREAS Barren flood plain areas, land fills, etc.

13. WATERCOURSES Main river channels.

temporary measures included removal of contents (50 and 100 percent), raising of contents (85 percent 3 feet) and temporary perimeter barriers (1, 2, and 3 feet).

Analysis of temporary installation of perimeter barriers (earthen dikes, seals, sandbags, etc.) were performed by the DAMCAL program based on user specifications of desired height of protection for each designated damage category.

Analysis of temporary removal of contents was performed by adjusting the base value of the contents factor of the DAMCAL composite damage function. The value would be zero for 100 percent content removal and 50 percent of the present conditions value for analysis of removal of half of the contents.

Analyses of raising contents were performed by modifying the stage-percent content damage relationship of the composite damage functions. Fifteen percent of the present conditions content values remained the same while 85 percent were adjusted upward three feet. The 15 percent was assumed reasonable for placement of personal goods on tables, chairs, etc., which would retain that current portion of the content damage potential.

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